

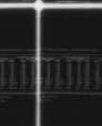
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COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
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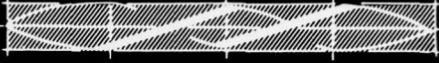
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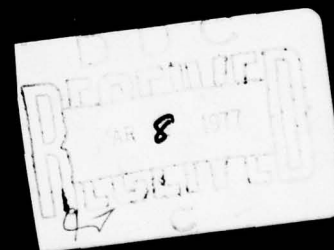
Columbia-North Pacific Region

Comprehensive Framework Study
of Water and Related Lands

APPENDIX

VII

FLOOD CONTROL

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PACIFIC NORTHWEST RIVER BASINS COMMISSION
1 COLUMBIA RIVER, VANCOUVER, WASHINGTON

JUNE 1971

This appendix is one of a series making up the complete Columbia-North Pacific Region Framework Study on water and related lands. The results of the study are contained in the several documents as shown below:

Main Report

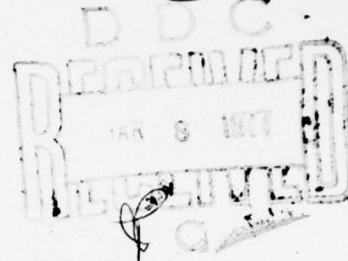
Brochure Report

Appendices

- | | |
|---|--|
| I. History of Study | IX. Irrigation |
| II. The Region | X. Navigation |
| III. Legal & Administrative
Background | XI. Municipal & Industrial
Water Supply |
| IV. Land & Mineral Resources | XII. Water Quality &
Pollution Control |
| V. Water Resources | XIII. Recreation |
| VI. Economic Base &
Projections | XIV. Fish & Wildlife |
| VII. Flood Control | XV. Electric Power |
| VIII. Land Measures & Watershed
Protection | XVI. Comprehensive
Framework Plans |

Pacific Northwest River Basins Commission
1 Columbia River
Vancouver, Washington

Flood Control



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APPENDIX VII

Columbia-North Pacific Region
Comprehensive Framework Study
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Prepared by
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410 072

AB

APPENDIX VII
FLOOD CONTROL

Prepared under the direction of the
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This appendix to the Columbia-North Pacific Region Framework Report was prepared at field level under the auspices of the Pacific Northwest River Basins Commission. It is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected States, and by the Water Resources Council prior to its transmittal to the President of the United States for his review and ultimate transmittal to the Congress for its consideration.

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INTRODUCTION

PURPOSE

The purpose of the Flood Control Appendix is to assess the flood problems of the region as they affect the overall development of water and related land resources and to prepare input data for plan formulation. Because flood damages and the threat of flooding limit the use of flood prone areas, an effective program to control these damages and to reduce or define the risks of flooding is an essential element of an overall water use program. Flow characteristics of most streams in this region are such that storage for flood control can be jointly used for conservation purposes thereby spreading the costs and enhancing the feasibility of each water use. Thus, final planning for flood control can be done jointly with other uses during the development of the overall framework plan. To fulfill the purposes of this appendix, two major goals were met: (1) the identification of major problem areas and (2) the presentation of structural and nonstructural programs that will reduce or eliminate the damages to these areas.

SCOPE

The study was preliminary or reconnaissance in nature. The principal sources of data were previous studies and reports by Federal and State agencies. Data on floods and flood damages along major streams are believed to include all floods that significantly affect the works of man but are limited to those which are of sufficient importance to have been reported to the Corps of Engineers. Data on upland or small tributary areas are fairly complete on croplands but rather sketchy on range and forest lands. Present and future average annual damages have been adjusted to 1967 price levels except in Subregions 9 and 11, which are based on the respective Type II studies.

METHODOLOGY

The existing flood control structures and measures were analyzed as to effectiveness in reducing flood losses. Then the remaining flood damage, including losses that may be attributable to existing economic development are pointed out. Also, as required background, existing economic development has been projected to indicate potential future flood losses in the absence

of additional measures. Guidance for the projections was taken from Appendix VI, Economic Base and Projections. From these data, approximations have been made of probable flood damage by the time frames used in this study.

PRESENTATION OF MATERIAL

The Regional Summary presents a history of floods of regional significance, which is largely a history of floods on the Columbia River, and the story of growth of flood control as a function of water resource development. It continues with regionwide information on existing structures and measures for control of floods, average annual damages prevented, and remaining average annual damages. The remaining average annual damages are projected by time periods to 1980, 2000, and 2020. Finally, a summarization indicates measures that could be taken to maintain future damages at a level consistent with maintaining the region's proportionate share of national growth.

Each subregion chapter includes a description of the area, the resources, and economic factors that pertain to the flood problems. A history of significant floods is also presented as well as a description of the effectiveness of existing protection, and an assessment of remaining flood problems. For each of the subregions, the economic parameters for projecting future flood damages are presented. A discussion also covers the many options by which present and future flood problems may be alleviated or minimized.

AGENCY CONTRIBUTIONS

The Corps of Engineers was designated lead agency for preparation of this appendix. It has furnished data on the flood control aspects of urban and downstream areas, generally those areas below a 400-square-mile drainage where major structural measures are necessary, and has coordinated the input from other agencies.

The Soil Conservation Service has furnished data on watershed protection and flood control needs of upland areas. The Forest Service, Bureau of Land Management, and Bureau of Indian Affairs, furnished data on lands under their administrations. The Bureau of Reclamation furnished hydrologic data on streams in areas where irrigation has been the primary water development. The National Weather Service (prior to October 4, 1970, known as the U. S. Weather Bureau) has furnished data on climate, flood stages, and availability of river forecasts. State and local agencies have contributed by supplying information and developing data.

REG-ONAL SUMMARY

REGIONAL SUMMARY

DESCRIPTION OF THE REGION

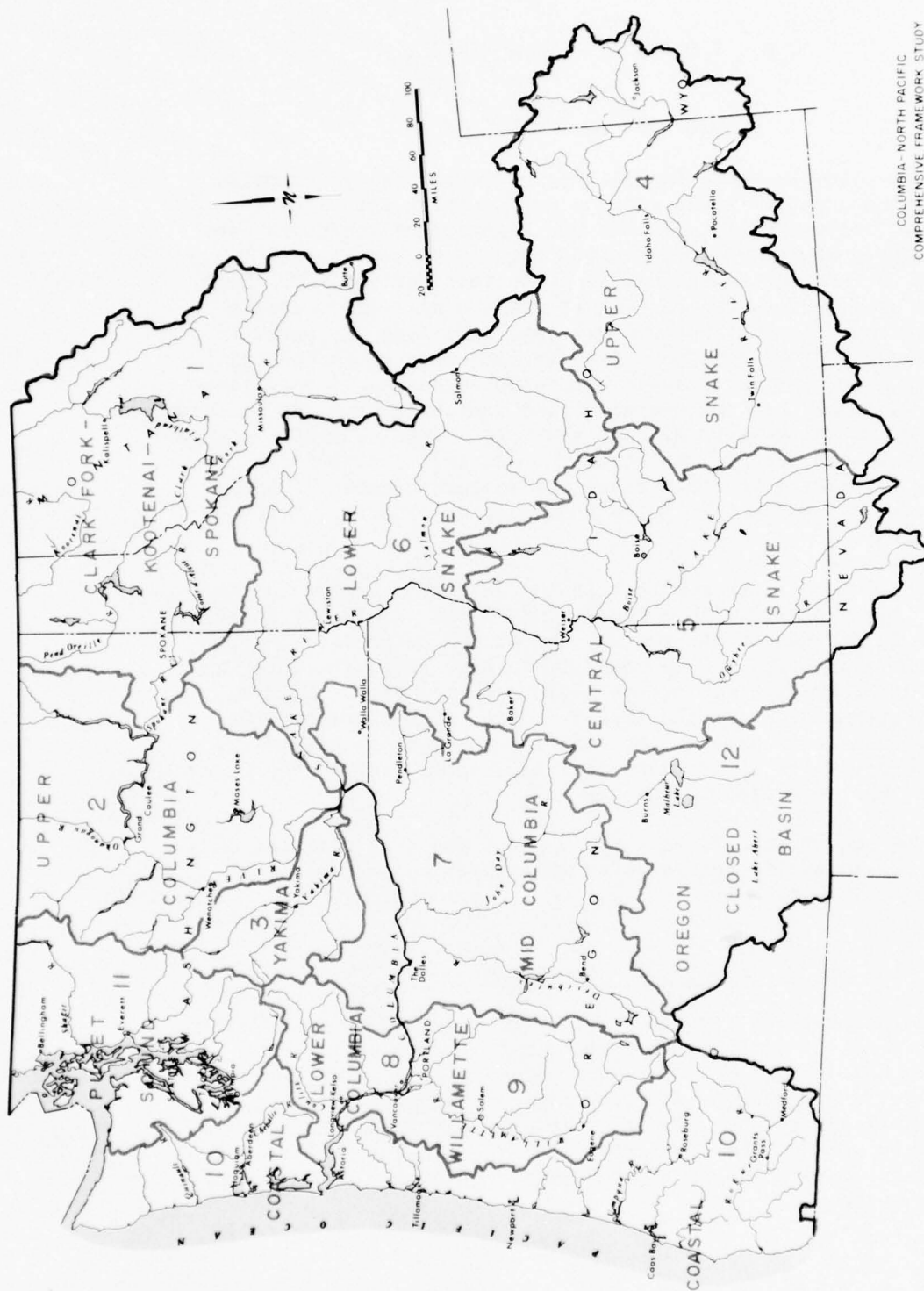
The Columbia-North Pacific Region comprises approximately 274,400 square miles in the extreme northwestern corner of the contiguous United States. It extends eastward on the north from Cape Flattery at the Pacific Ocean along the United States-Canada boundary to the Continental Divide in western Montana. On the south it extends from the Pacific at the southwestern corner of Oregon eastward to southwestern Wyoming, excluding the portions of the Klamath River and Goose Lake drainages in south central Oregon and the Bear River Basin in southeast Idaho. The eastern boundary follows the Continental Divide southerly from the Canadian border to central-western Wyoming and then swings southwesterly to the southwestern part of the state to intersect the southern boundary. The Pacific Ocean forms the western boundary. Land areas total 271,400 square miles and large water areas, 3,000 square miles.

The Columbia River system is the largest drainage in the region. Its drainage within the United States is 219,400 square miles or 80 percent of the region, and it drains another 39,500 square miles in Canada. The coastal drainage area, including the Puget Sound Subregion, comprises 37,100 square miles. Numerous stream systems, of which the Skagit, Rogue, and Umpqua are the largest, drain this area. The remaining area, which consists of 17,900 square miles in southern central Oregon, lies in the Great Basin and has no outlet to the sea.

The region is divided into 12 water resource planning subregions corresponding generally to major hydrologic drainages (see figure 1).

Geology and Land Forms

Although the region has a variety of rock types, its outstanding characteristic is the predominance of volcanic rocks. More than half of the region is underlain by lava flows, pyroclastics or sedimentary rocks composed of volcanic materials. Other rock types include granitic, metamorphic, and consolidated sedimentary rocks which are largely confined to the southern Coast Range, the northern Cascade Range, and ranges of the Rocky Mountain system.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY
THE C-NP SUBREGIONS
THE REGION
1968

Figure 1

The region is composed of several distinct physiographic provinces: (1) the Coast Range and the Klamath and Olympic Mountains running generally north and south along the western edge of Oregon and Washington; (2) the Puget Sound-Willamette Valley Trough paralleling the Coast Range; (3) the Cascade Range forming the east side of the trough; (4) the Columbia Plateau in east central Washington and north central Oregon; (5) the Blue Mountains of northeastern Oregon and southeastern Washington; (6) Oregon Closed Basins; (7) the Northern Rocky Mountains comprising the Bitterroot, Cabinet, Selkirk, Salmon River, Okanogan Highlands, and associated mountain ranges in northern, central, and eastern Idaho, western Montana, western Wyoming, and northeastern Washington; and (8) the Snake River Plateau of southern Idaho, northern Nevada, and southeastern Oregon.

Climate

The climate of the region is influenced by the southerly and easterly drift of cyclonic storms that develop in the northern Pacific Ocean, and by the seasonal migration of the semi-permanent high-pressure anticyclonic area of the central Pacific. In winter, storms pass over the region causing most of it to have distinctly wet winters. Because the storms pass farther north in summer, most of the region has relatively dry summers; however, in the interior, continental airmasses occasionally bring summer rains. The general eastward movement of marine air over the area keeps temperatures moderate most of the time. Occasionally, however, continental high-pressure areas reverse the general surface flow, and dry air--hot in summer and cold in winter--moves westward rather than eastward.

In general, the climate of the western part of the region is characterized by wet, but relatively mild, winters and warm dry summers. The severity of the climate increases eastward from the Pacific Coast. The mountain ranges cause marked climatic changes, and the interior ranges of the basin lie in a transition zone between the maritime regions of the Pacific Coast and the continental climate of the Great Plains. The Columbia Plateau is generally semi-arid, with little or no precipitation during the summer growing season and only small amounts during the winter. Mountainous areas on the other hand receive relatively large amounts of winter moisture. Appendixes II and V contain more detailed information on the climate of the region.

Temperature

West of the Cascade Range, temperatures in the low-lying areas range from a January average of 36°F. to a July average of 62°F. The frost-free season ranges from 120 to more than 240 days in length, covering the period April to November. Mountain areas are colder year-round and have a much shorter growing season. Seasonal variations in mean daily temperature are about 15°F. along the coast, and 25°F. and 30°F. in the interior valleys and in the mountains. Except in the southern part, temperatures above 100°F. are rare. Temperatures below 0°F. have occurred, but in the lower valleys, temperatures below 10°F. are unusual.

East of the Cascade Range, temperature patterns are quite different. Average January temperature ranges from 20°F. in the mountains to 32°F. in the warmest valley areas, and average July temperature similarly ranges from 60°F. to 78°F. Seasonal range in mean daily temperature varies between 40°F. and 50°F. At most stations, temperatures well above 100°F. have been recorded in summer, and temperatures of -30°F. are fairly common in winter, and some below -50°F. have been recorded. In the mountains and in the Oregon Closed Basin, the frost-free growing season is generally less than 100 days, extending from mid-June to mid-September. In the valleys on the Columbia Plateau and on the Snake River Plain, the frost-free season is 140 to 200 days long, from late April to late September.

Precipitation

Two major factors generally affect precipitation, the moisture supply (the Pacific Ocean) and elevation. Regardless of elevation, however, the western parts receive by far the most precipitation. At the same distance from the ocean, the higher mountains receive more than the valleys and plateaus. Inland, and at higher elevations, a larger percent of total precipitation occurs as snow (see figure 1).

The heaviest annual precipitation in the conterminous United States occurs on the western slopes of the Coast and Cascade Ranges, exceeding 200 inches in some areas. From the crest of the Coast Range, annual precipitation decreases to about 35 inches in the Puget Sound-Willamette Trough, then increases again to 100 inches or more along the crest of the Cascade Range. Nearly all precipitation comes with storms moving in from the ocean, and about two-thirds of the year's total falls during the October to March period. At lower elevations, it is largely rain, but in the mountains, usually snow. Heavy snowpacks on many of the higher mountains have formed glaciers which are the

sources of several rivers. Maximum snowpacks, occasionally to depths of 20 to 30 feet, are generally found at elevations above 5,000 feet, and their water content usually is greatest in late March and early April. Variations in annual precipitation range from about 60 to 150 percent of average.

East of the Cascade Range in central Oregon and Washington, precipitations amount to 10 inches or less in the valleys and on the plateaus. However, the mountain areas have total precipitations of 40 to 50 inches, much of it as snow. General area-wide storms moving in from the west bring the bulk of the precipitation, but late spring and summer convective storms, which cause occasional floods, are sufficiently common to produce significant runoff. Although recorded rainfall intensities rarely reach 1 inch per hour, weather stations are scattered and much greater intensities are known to have occurred. Variations in annual precipitation are somewhat greater than west of the Cascade Range, ranging from 50 to 165 percent of the average.

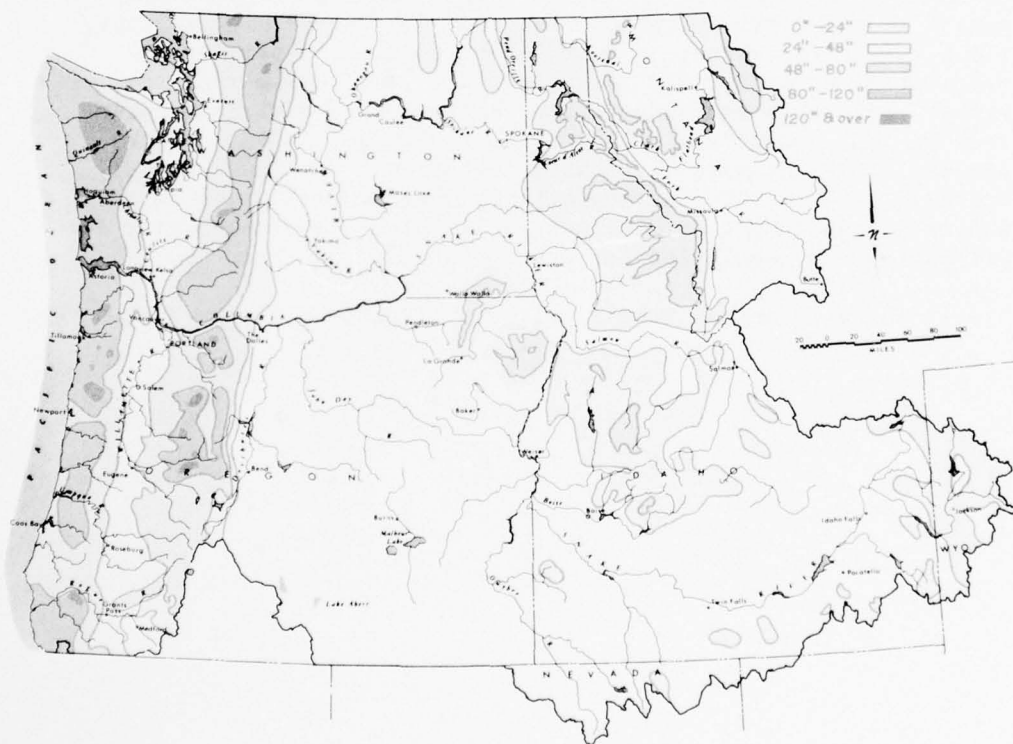


FIGURE 2. Patterns of Mean Annual Precipitation.

Streamflow Characteristics

Streams originating in the Coast Range or on the western side of the Cascade Range respond rapidly to the rainfall characteristics of the area, and the flood period occurs from November through March.

Mountain snowmelt west of the Cascades seldom causes over-bank flows, but may augment rain caused floods. Occasionally, floodflows from the lower Columbia River drainages in Subregions 8 and 9 combine with above average flows from the lower elevation areas east of the Cascade Range and cause winter floods on the lower Columbia River.

East of the Cascades, precipitation amounts decrease markedly, and the principal runoff comes from the higher elevation areas. In these areas, the precipitation generally falls as snow, and runs off during the spring and early summer. Occasionally, warm rains fall over the lower areas east of the Cascades and runoff from the precipitation plus snowmelt causes high streamflows during the winter. Characteristically, the streams originating at higher elevations exhibit low flows during the winter, gradually increase during the spring to a maximum during June or July and decrease rapidly to low stages by the end of summer. Other streams which have significant portions of their drainage below 4,000 feet reach their maximum discharges during winter floods. Most streamflows reflect the use of the water for irrigation and regulation for power and flood control.

The mean annual runoff pattern is shown on figure 3.

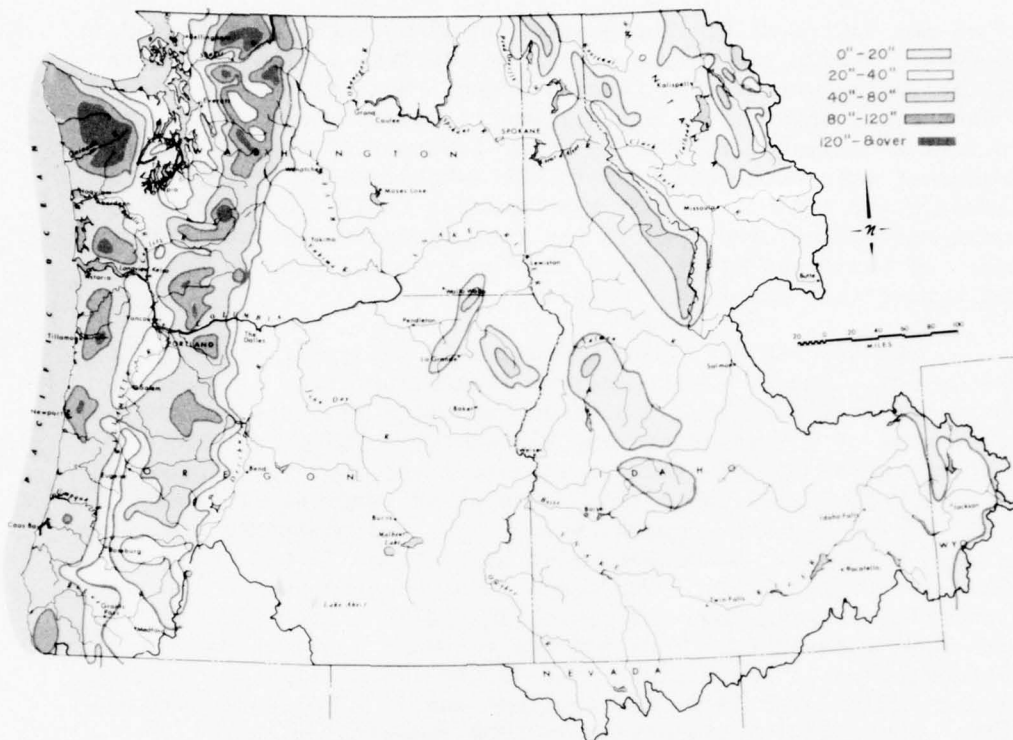


FIGURE 3. Patterns of Mean Annual Runoff.

Regional Economy

The Columbia-North Pacific Region has a young but maturing economy. The region's population increased from about 13,000 in 1850 to nearly 6 million at the present time. This growth resulted from increasing economic activities based primarily on the utilization of abundant natural resources. Forests, farmlands, minerals and fish have been the historical foundation of its development, increasingly supplemented by more intensive use of the water resource for irrigation and hydroelectric power. In the recent past, the historical dominance of the natural resource industries has been reduced by the growth of other industries, creating a broader and more mature economic base.

Regional population growth rates have exceeded the national rates in all but 2 of the last 10 decades. Between 1940 and 1965, the population grew by 70 percent compared with national growth of 47 percent. The population density in 1965 was just over 22 persons per square mile, a density well short of the national average

of 55 per square mile. The population is unevenly distributed, however. Nearly two-thirds of the people live in the one-fifth of the region west of the Cascade Range. Most of these reside around Puget Sound or in the Willamette Valley where favorable factors of climate, rich soil, water transportation and timber resources have been conducive to the establishment of centers of industry and trade. East of the Cascades smaller population concentrations have developed in the rich irrigated agricultural areas of the Snake River Plain and the Columbia Plateau and in the mining centers of the Rockies.

The forests have been historically the greatest wealth of the region. Forest lands comprise 86 million acres or approximately half of the total land area, and wood products account for 35 percent of all manufacturing employment. Value added by production in the forest products manufacturing industries amounted to nearly \$1.7 billion in 1963. Mining is important in some parts of the region. Copper, lead, zinc, and phosphate are major mineral products. Anadromous fish populations in the Columbia River system and coastal and Puget Sound streams have supported a commercial fishing industry since the middle of the 19th century, and sport fishing for these and the resident trout, Kokanee and other species is increasing. Out of the 174 million acres in the region, 21 million acres are cropland and 59 million are rangeland. Agricultural production in 1964 amounted to over \$1.5 billion and values added in food and kindred products industries amounted to an additional \$745 million. Production is expanding but because of rapid productivity gains, agricultural employment declined from 18 percent of total employment in 1940 to 7 percent in 1960.

The changing character of the economy has recently been most evident in its manufacturing sector. Manufacturing grew from 19 percent of total employment in 1940 to nearly 23 percent in 1960. During this same period, employment in the resource-based industries of food processing and timber industries increased 40 percent, but growth of other manufacturing was so great that although these industries accounted for nearly 70 percent of manufacturing employment in 1940, by 1960 they had declined to less than one-half. Employment in mining decreased more than 50 percent from 1940 to 1960 reflecting increased mechanization in some mines and discontinued production from others. Processing of primary metals, largely aluminum, increased sharply during the same period.

The region generally is well served by water, rail, highway and air transportation. Water transportation by inland rivers, the Pacific Ocean and the Puget Sound waters have been significant in the region's development. The Columbia River is the most

important of the inland waterways. It has been continually improved for navigation; improvement of the entrance bar and the lower river permits deep-draft traffic to reach Portland and Vancouver. Barge traffic now extends 328 miles up the Columbia River to Pasco, and 100 miles on up the Snake by a combination of channel improvement and slackwater navigation. With completion of Lower Granite Dam, slackwater navigation for barge traffic will be extended to Lewiston, Idaho. The Willamette River permits ocean-going traffic to Portland and barge and log-raft traffic as far upstream as Corvallis.

Seaports in the Puget Sound area have adequate depths to serve all ocean-going vessels engaged in intercoastal and inter-continental trade. Ports and the harbor transfer facilities have grown to meet the needs of the trade. Ports serving the ocean trade have also developed along the lower Columbia River. Several ports on the Oregon and Washington coast have been developed to serve the oceanic timber trade.

The population of the region, 5.9 million in 1965, is projected to reach 7.6 million by 1980, and 15.4 million by 2020. The population distribution is not expected to change materially. In consonance with past trends, though, growth is expected to be focused more in urban areas with the population of small towns and rural areas showing either little growth or a decline.

Increasing efficiency in agricultural methods will be principally responsible for the declining percentage of rural population. By 1980, agricultural employment is projected to be four percent of the total employment; by 2000, three percent; and by 2020, two percent.

HISTORY OF FLOODING

Early Settlement

The drainage features and the volume of the streamflow of the Columbia River contributed extensively to the settlement of the region. The drainage courses offered routes which led to early exploration and settlement. Lewis and Clark made their way over the divide from the Missouri River Basin into the river's headwaters and followed streams westward to the mouth. Later, emigrants from the plains trudged westward to headwaters of the Snake River and followed its westward course to the Oregon Country. A generation later, the transcontinental railroads used the water grades of the stream courses to reach the Pacific Ocean from mid-continent points. Somewhat prior to the railroads, the Columbia and Snake Rivers had become avenues of transport from seaports to inland points. These access routes had a major influence on

settlement of the region and communities tended to locate adjacent to navigable streams, often in the flood plains.

Early settlers of the Columbia-North Pacific area gave little thought to the flood risks in selecting homesteads or sites for communities. Floods exacted a heavy toll for this oversight, and the history of the region notes many instances of hardships brought on by floodwaters. One of the more notable early events occurred in December 1861 in the Willamette River Basin, which had been the destination of many of the emigrants. Nearly all settlements were located along some stream and had experienced some flood damages. The December 1861 flood destroyed several communities including Champoege, the site of the first American government in the Oregon Territory.

Flood Records

Records of maximum annual stages on the Columbia River date back to 1858 at The Dalles, but records of daily discharge were not kept prior to 1878. Records for the Spokane and Willamette Rivers also are available prior to this century, but records for most other streams in the region date back no further than the beginning of the century. High water marks from historical floods back to the middle of the 19th century have been located at many locations but generally are not considered part of the streamflow records.

Types and Characteristics of Floods

Most major Columbia River floods stem from melting of the winter snowpack during late spring and early summer. The snowmelt may be augmented by rainfall, but the latter is usually of a localized nature and snowmelt is the dominating factor of the Columbia River floods. Much of the annual precipitation falls as snow during the fall, winter, and early spring seasons over the higher elevation areas. The accumulated snow melts in late spring and summer. Floods resulting from the snowmelt rise gradually to a peak and high flows last for a considerable period. The volume can be predicted quite accurately. Such floods are characteristic in areas east of the Cascades.

Convective storms also cause floods in the areas east of the Cascade Range. Such storms do not cover large areas but may be accompanied by intense rainfall of relatively short duration. Peak discharges from limited areas may cause extensive localized damages. Floods of this nature occur somewhere in the region almost every year but have little effect on major streams.

Widespread, warm, winter rainstorms also cause floods east of the Cascade Range in areas generally below 4,000 or 5,000 feet in elevation. Such floods are relatively rare, but effects are usually compounded by snowmelt, frozen ground, and/or ice in the streams and severe damages may result.

West of the Cascade Range most floods are caused by rainfall, although major floods may be augmented by snowmelt and most streams draining areas above 4,000 or 5,000 feet elevation also have spring freshets. The rainfall floods result from one or a series of moisture-laden winter storms moving inland from the Pacific Ocean. Such floods peak within a few hours or days and the flows recede rapidly to within bank stages. However, other series of storms having flood-producing potentials may follow an original storm or series at intervals of about a week and streams may be at or above flood stage for several weeks at a time. Most major rainfall floods occur between the middle of November and the end of February with the peak activity in late December and early January. Such floods are frequently preceded by a period of wetter than normal weather that thoroughly saturates the ground.

Historical Floods of Regional Significance

All major Columbia River floods are of regional significance. Not only do these floods affect the flood plains along the lower Columbia River, but the waters that build up the floods cause significant flooding in many tributary streams before reaching the Columbia. Thus, the flood of June 1948, the second highest known on the lower Columbia, also caused extensive flooding in Subregions 1, 2, 3, 6, and 7. Major winter floods become of regional significance when the storms cover a broad front and extend inland to or beyond the Rocky Mountains.

June 1894

The largest known flood of region-wide significance was that of June 1894. (7) Available data indicate that the flood was severe throughout the Columbia River Basin, except on the tributaries draining the Cascade Range. The flood resulted from rapid melting of an abnormal snowpack that had accumulated throughout the basin during the preceding winter. It caused considerable damage on most of the tributaries and on the upper and lower reaches of the Columbia River. Maximum discharge has been estimated at 680,000 cfs at the International Boundary and 1,240,000 at The Dalles.



Looking west on Washington Street, Portland, Oregon, June 1834. (USCE)



The same corner, 1970. (USCE)

The flood remained above bankfull stage at Vancouver for 74 days and above major flood stage for 38 days. The maximum stage at Vancouver was about 36.2 feet, mean sea level, 18.4 feet above flood stage. Backwater from the flood caused a similar stage on the Willamette River at Portland. The flood inundated all the bottom lands along the lower Columbia River including all or parts of the towns of Kelso, Kalama, and Vancouver and the area now occupied by Longview. More than 300 blocks in the downtown area of Portland were covered (see photos), and railroads leading north and east were closed. An estimate of the damage is not available, but newspaper accounts noted that damage was extensive. High water marks indicate that most upstream tributaries experienced stages higher than have since been recorded. In the Clark Fork-Pend Oreille system, over 32,000 acres were flooded in the Flathead Lake area and in the valley of the Flathead River upstream from the lake. The flood is estimated to have increased the level of Flathead Lake about 4 feet above other known floods. About 16,000 acres were flooded around Pend Oreille Lake, including part of the city of Sandpoint, although information does not indicate the extent of flooding in the town. Studies show about 32,000 acres along the Pend Oreille River downstream from the lake would be flooded by a comparable flood.

On the Kootenai River, the flood inundated 70,000 acres known as Kootenai Flats in which Bonners Ferry lies. Partial records at the outlet to Kootenay Lake near Nelson, Canada, date back to 1891. The 1894 flood had the greatest discharge of record, although the stage at Bonners Ferry has been exceeded by several recent floods because of confinement by levees in the area.

Areas around Coeur d'Alene Lake and in the City of Spokane were flooded but information is unavailable as to the extent of damages. Snake River also had the highest known flows and stages, but data are too limited to include any description of conditions during the flood at any specific location.

May-June 1948

In May and June 1948, a devastating spring flood hit the Columbia River Basin. (11) The winter of 1947-1948 had not been particularly severe and data about the first of April indicated that the water content of the accumulated snow in the mountain areas of the basin was only 97 percent of normal. However, spring was abnormally late and in many areas the snowpack water content was greater about May 1st than in April. Temperatures remained subnormal over the entire basin until the middle of May, then became abnormally warm. After 2 weeks of warm weather, near record flooding occurred throughout all portions of the basin

east of the Cascade Range except the Snake River Plateau. General rains on May 28 and 29 were extremely intense in several localities, particularly over the basins draining the east slopes of the Cascade Range in Washington. The weather remained favorable for rapid snowmelt through the first 10 days of June.

While the flood, with a peak discharge of 1,010,000 cfs, was smaller than the 1894 flood (and about equal to one which occurred in 1876), it provided much information on characteristics of major floods that were unavailable prior to that time. Streams draining Montana, northern Idaho, and northeastern Washington had major floods. Also, the eastward draining slopes of the Cascade Range and the Salmon and Clearwater tributaries of the Snake River were major contributors. Some had the highest discharge of record up to that time.

The area downstream from Bonneville Dam had the most extensive damage. Considerable flood plain area was behind levees which failed, and backwater on the Willamette River inundated industrial areas and transportation facilities in Portland. A levee protecting a war-time housing project (Vanport) in North Portland failed completely, destroying the entire project (see

Break in the railroad fill which formed the west leg of the levee around Vanport, May 30, 1948, 5:30 p.m. (USCE)



The same break after flow had stabilized. (USCE)

photos). All major waterways, railway lines, and navigation facilities serving the Portland-Vancouver area from the east, north, and west were severed, and the Portland and Vancouver airports were flooded. Levees protecting 18 districts along the lower Columbia River were breached or overtopped, flooding over 35,000 acres. The river remained above bankfull stage for 51 days and above major flood stage for 26. In most flooded areas all vegetation was killed and the water receded too late to allow replanting that year.

Heavy flooding occurred throughout Subregions 1, 2, 3, and 6. Notably the levees in the Kootenai Flats area from Bonners Ferry to Kootenay Lake in Canada were breached or overtopped and 36,000 acres in the United States and 8,000 acres in Canada were flooded.

Throughout the basin, approximately 582,000 acres were inundated and 5,000 homes destroyed. Nearly 35,000 people were made homeless and about 100,000 temporarily evacuated. Thirty-eight lives were lost. Total damages exceeded \$100 million.



Vanport, Oregon, May 30, 1948, 5:30 p.m. (USCE)

June 1876

The third largest flood of historical record on the Columbia River occurred in June 1876. From stages along the lower Columbia River, it has been estimated to have been only slightly smaller than the flood in June 1948. Very little other detail is available.

December 1933

In December 1933, heavy precipitation covered southern Washington and northern Oregon and extended eastward into Idaho to the Spokane and the North Fork Clearwater River Basins. The storm caused record flood stages on the Tualatin, Molalla, Cowlitz, Lewis, and Nisqually Rivers west of the Cascade Range and on the Yakima, Coeur d'Alene, St. Joe, North Fork Clearwater and St. Regis Rivers farther east. On the lower Columbia River, the maximum stage at Cathlamet, about mile 40, was only 2 feet below the June 1894 flood level and farther downstream the flood, together with high tides, produced the highest stages ever recorded (10) although a high water mark on a railroad bridge at Astoria indicates that a higher tide occurred in December 1894.

December 1964, January 1965

The December 1964-January 1965 flood was in reality two distinct events but is considered as one, largely because of the impracticability of separating the effects of one from the effects of the other. Heavy fall rains thoroughly saturated the soil west of the Cascade Range and partially saturated it over the balance of the region. Mid-December brought subfreezing temperatures followed first by snowfall and then by warm heavy rains. The storm caused extensive flooding, in many instances the highest stages ever recorded, throughout the area from San Francisco Bay to the Columbia River and inland to Reno and Winnemucca, Nevada, and Pocatello, Boise, and Coeur d'Alene, Idaho. (32) Greater than normal precipitation continued over much of the region through January, but much of it fell as snow. Late in January, a series of intense, warm storms caused renewed flooding. Major floods, again on some streams the highest ever recorded, occurred from the north-central coastal area of Oregon eastward to southeast Washington in the area around Lewiston, Clarkston, Moscow, and Pullman. Streamflows responded quickly to the warm, heavy precipitation. Most streams crested within 2 or 3 days and were back to normal in little more than a week.

Throughout the region more than \$185 million damages were reported (4, 23), 18 lives were lost from flood-related causes, and 671,000 acres of agricultural land were flooded. ^{1/} Key bridges and whole sections of highways and railroads were washed out. All routes east from the Willamette Valley were closed and floods in northern California cut Interstate 5 and the coast highway. Rescue and repair activities in and east of the Cascade Range were hampered by the January snows. Livestock was lost because the December flood had destroyed winter feed stockpiles and the damaged roads and snows prevented resupply.

Extensive as the damages were, they would have been worse without the existing flood control projects. Federal flood control projects, projects under Federal coordination for flood control, other projects providing incidental control of flooding, and flood fight activities prevented damages in excess of \$650 million. Most of the damage prevention was in the Willamette Basin. Without the flood control reservoirs, the Willamette flood



Flood damage along the North Umpqua River, January 1965. (USCE)

^{1/} The Corps of Engineers records acreages of rural lands flooded but only dollar values in urban areas. The acreage cited includes a minor amount of duplication of lands flooded by both the December and January floods.

would have been nearly equal to or in some areas slightly in excess of the historic flood of 1861. The greatest damage would have been in the Portland area. The peak flows on the Columbia and Willamette Rivers would have combined and caused a stage at Portland that would have been 1 foot higher than during the great spring flood of 1894, which covered more than 300 blocks in the city. It was estimated that high velocities in the Willamette could have destroyed all bridges in the city except the St. Johns suspension bridge. All communication and power distribution would have been disrupted, and a very real threat of extensive fire damage would have existed.

DEVELOPMENT OF FLOOD CONTROL IN THE REGION

Early efforts to control floods in the region followed a pattern of local protection for those areas subject to more frequent damage. Levees and floodwalls for protection of individual areas around estuaries and along the lower 120 miles of the Columbia River constituted much of the early effort. Following major winter flooding in 1933, local interests in the Willamette Basin initiated engineering studies to investigate the feasibility of structural protective measures to control floods, and further studies were made of the lower Columbia River area.

At that time, a Federal interest in solution of flood problems had not been established on a nationwide basis. Prior to the turn of the century, Congress had established the Mississippi River Commission and the California Debris Commission with limited Federal interest in flood control, incidental, however, to the improvement and preservation of navigation on the Mississippi River and the Sacramento-San Joaquin Rivers. Following disastrous floods in 1915 and 1916, funds were appropriated for the specific purpose of controlling floods on those streams.

A growing Federal interest in flood control and other water uses stemmed from the comprehensive river basin investigations authorized by Congress in 1927. These "308" studies, so-named with reference to House Document 308, 69th Congress, which recommended surveys of most major river basins throughout the country, called for development of general plans to consider, among other factors, the control of floods. The first "308" report on the Columbia River, completed in 1931, provided some assessment of flood problems. (6) It was not, however until the Flood Control Act of 1936 that Congress defined a broad Federal interest in flood control and authorized numerous flood control projects throughout the country.

The initial Federal flood control authorizations in the Columbia Basin included several new levees and improvements to 30 or more existing levees in the lower Columbia River area, bank protection works in the Willamette Basin, and new local protection projects or improvements to existing projects on the Umatilla, Lewis, and Cowlitz Rivers. In the Puget Sound area, projects authorized by the 1936 Act included channel clearing and bank revetment on the Stillaguamish River, bank protection on the upper Puyallup River, and two projects for protection of the City of Tacoma and adjacent areas, one a local protection project on the Puyallup River and the other an upstream storage reservoir, Mud Mountain Dam, on the White River.

Subsequent flood control acts added many additional protection projects in the region. Meanwhile, a comprehensive Columbia River "308" review report was authorized by Congress in 1943 to consider all water resource needs in the basin. The study was underway when the disastrous flood of 1948 occurred, producing widespread damages in nearly every part of the region and particularly in the lower Columbia River area. The inadequacy of the local protection system pointed not only to the need for its extensive improvement but also to the desirability of upstream storage for control of flows in the lower river area. Widespread flooding in local subbasins also demonstrated the need for additional local protection projects throughout the region.

Lower Columbia River Flood Control

The review report completed in 1948 and subsequently submitted to Congress as House Document 531, 81st Congress (7), recommended a multiple-use storage plan incorporating regional flood control as one of its most significant functions. The storage objective was to reduce the maximum flood of record to a peak flow of 800,000 cfs at The Dalles. The resulting plan, designated the "Main Control Plan," provided for the utilization of 23 million acre-feet of storage in eight reservoirs on the Columbia River and major tributaries. In conjunction with the upstream storage, the plan provided for the improvement of the lower river levee system for protection against a corresponding design flow.

Nearly a decade after the 1948 flood, only a small fraction of the storage included in the above plan had been constructed or appeared attainable and a review of the plan was initiated at the request of responsible regional interests. The study was authorized in 1955 and the basic report was completed in 1958 (8). Prior to publication of the report, a treaty between the United States and Canada relating to cooperative development of the water resources of the Columbia River Basin was signed. (5) A

reanalysis of the basin's needs, in response to the treaty developments, found that the storage that would result from the treaty, when added to the storage then existing and under construction, would reduce the 1894 flood to 720,000 cfs at The Dalles. The study further detailed a plan to reach an ultimate objective of reducing the 1894 flood to 600,000 cfs at The Dalles. As of 1970, projects existing and under construction will reduce a flood of 1894 proportions to 670,000 cfs at The Dalles (see table 82). This degree of control will enable levees and other local projects to provide adequate protection to most flood prone areas along the river even in areas where such protection has not previously been feasible. It also means that additional upstream storage for flood control will have very little downstream beneficial effect.

Snake River

In the Snake River Basin, irrigation has been the determinant force in water resource development. The Bureau of Reclamation, as well as private enterprise, has built many large storage projects to supply irrigation water. Most of these reservoirs, especially those built before the 1940's, were constructed primarily to assure an irrigation water supply and consequently were operated to fill with first available water. As storage was added and methods improved to forecast runoff from snowmelt, the reservoirs have been operated to a greater extent to assist in controlling floods and flood control has been included as a project purpose in the construction of many recent reservoirs. As a result, a high degree of control has been obtained on the Snake River and several of its large tributaries, although a specific flood control objective has not been established. For instance, a flood on the Snake River with a natural peak of 130,000 cfs at Weiser, Idaho, such as occurred in 1894, would be reduced to about 44,000 cfs. However, areas where damages are concentrated still require supplemental local protection.

Subregion Flood Control

Multiple-purpose storage has also been effectively utilized in alleviating flood problems in other subregions. In general, however, single-purpose flood control measures have been the solution to localized problems. These measures include some single purpose flood control storage, a great number of local levees, and many channel stabilization and improvement projects. Small reservoirs and farm ponds reduce damages in the immediate vicinity of those structures. Watershed treatment and soil conservation measures reduce the amount of silt washed into the

streams by major storms. Incidental control of flooding has been effected in some areas by irrigation diversions and by storage primarily for irrigation or power.

Flood Damage Evaluation

The economic impact of flooding and the value of flood control projects are measured herein in terms of flood damages and damages prevented, usually expressed as an average annual value. Average annual damages are defined as the weighted average of all damages that would be expected to occur yearly under specific economic conditions and development and considering all likely floods and the probable occurrence of each.

Basic data on the nature and extent of flood damageable property in each flood plain area have been taken from reports of previous post-flood damage surveys and evaluated, reappraised, and correlated to other flood stages taking into account other characteristics such as velocity, duration, timing, and other pertinent factors. The reevaluated data were then converted to average annual damages by relating damages to flood magnitude to frequency and projected from the base year 1967 to 1980, 2000, and 2020.

On a regional basis the most extensive information was obtained following the May-June 1948 and December-January 1964-1965 floods. Surveys of these and other recent, more localized floods extended and verified damage data that had been obtained on many streams and areas over a period of years and provided firm and recent data upon which to base average annual damage computations. In some areas, more complete data were available from on-going project studies, and in other areas stage-damage relationships are kept up-to-date with constant revisions. Data for Subregions 9 and 11 were taken from the respective type II studies and are based on 1966 and 1965, respectively, prices and developments. The base year for all other subregions was 1967.

Flood Control Methods

The term flood control implies a means of controlling floodwaters but is applied synonymously to control of damages resulting from floods. Control of floodwaters immediately suggests a structure such as a storage reservoir, levee, or channel improvement. These methods, now generally referred to as structural measures, along with emergency flood fight activities, flood forecasting, and land treatment to prevent erosion and retard runoff have been the principal tools used for flood control. Society

gradually has recognized that all lands cannot be made flood free. This recognition has led to the concept that some flooding may be permitted but that development and use must be compatible with the hazard and possibility of losses minimized. As a result, flood plain use regulations, flood proofing and insurance have been added to the list of tools available to the land use planners as a means to assist in controlling or mitigating future flood losses.

Storage

Storage is the most effective measure for flood control. It may be either in a detention type reservoir or in a storage reservoir. A detention reservoir, as the name signifies, is temporary storage to control a flood peak to a predetermined quantity. A storage reservoir, on the other hand, accomplishes control of floods in a similar manner, but the stored water may be retained for some conservation use. In other words, storage may have a multiple use in a storage reservoir, but only a single use, flood control, in a detention reservoir. Detention reservoirs have limited applicability in this region where storage is generally compatible with multiple use.

Irrigation Storage and Diversions

Irrigation diversions of streamflows for storage and for field application tend to reduce floodflows. Throughout the entire portion of the region east of the Cascade Range, the general season of maximum flood hazard coincides with the season of substantial diversion. The extent by which streamflows are depleted is equivalent to storage for control of flooding. The amount of these diversions is known and is included in flood routing studies made to determine the optimum use of reservoirs. A somewhat similar diversion is possible in portions of the upper Snake Basin where excess streamflows could be diverted through porous lava formations into the extensive groundwater aquifer.

Levees and Channel Improvements

Levees and channel improvements including bank protection were the earliest structures for flood control in the Columbia-North Pacific Region and remain among the more important structural measures. Levee protection has several deficiencies, however, in that protection is limited, that some levees increase water surface levels in adjacent areas, and that overtopping or failure may be catastrophic. Channel improvements include clearing,

widening, and straightening to increase the carrying capacity, and bank stabilization to prevent erosion. Channel improvements or levees are frequently needed downstream from storage projects to allow evacuation of stored floodwaters during the flood season.

Diversion

Diversion to some other water course is another structural means of reducing flood stages. It has been an effective means in other regions but has limited applicability here. At most places where diversions might be possible, the stream to which peak flows might be diverted would be flooding at the same time and flood problems along its course would be intensified. One instance where diversion offers a feasible solution to a specific flood problem is on the lower Skagit River in the Puget Sound Subregion.

Flood-Plain Use Regulations

Flood-plain use regulations are needed to supplement structural measures since structural measures do not completely eliminate all possible hazards. Regulations need not be limited to supplementing structural measures. In instances where existing or probable future development does not warrant structural measures, regulations could assure future use consistent with flood hazards. Regulations should not be purely negative, but should designate appropriate uses of the flood plain as well as proscribing those that are inappropriate. Regulations are most urgently needed for flood plain areas in and adjacent to growing communities where both flood free and flood plain areas are available for development.

Local governments are responsible for adopting and enforcing flood plain use regulations, but in most instances do not have the capability of determining the extent and frequency of hazards. The Federal government provides flood plain information reports to show this information and gives informal advice as to scope and content of regulations.

Flood Proofing

Flood proofing consists of modifying existing or new structures to minimize damage to contents and buildings during floods.

Flood Forecasting

Forecasts of probable flood peaks, which rely on snow surveys and weather analyses, allow optimum use to be made of available storage reservoirs, stockpiling of supplies and organization for flood emergency activities, and evacuation of people and property endangered by floods. In this region, long range forecasts as much as 5 months in advance of the Columbia River spring freshet provide guidance for evacuating reservoirs; short range forecasts warn of winter rain and snowmelt floods 2 days to a week in advance; and tsunami or high storm tide warnings may be issued only a few hours before the event.

Emergency Activities

Flood emergency activities supplement all other means of flood control. The principal activities are evacuation, patrolling, and sandbagging or similar works. During the flood situation, the flood fight team takes such action as necessary to maintain and extend the existing protective works, and, as the situation permits, does any work feasible to alleviate the impact of the disaster.

Land Treatment Measures

Land treatment measures are the conservation practices that are applied and maintained on the land to hold the basic soil resource in place, increase its permeability, and allow it to absorb and retain more water. Cropland measures include terraces, strip-crops, contour plowing, stubble mulching, and cover crops. Forest and rangeland measures needed to assure an adequate vegetative cover include range seeding, grazing management, tree planting, road and trail rehabilitation, proper cutting practices, and fire protection. Proper land use and treatment assist in reducing sedimentation and peak flows, especially during floods of short duration, and assure continued productive capacity of the land.

Comprehensive Watershed Treatment Programs

Comprehensive programs, comprising appropriate land treatment measures, erosion control structures, storage, levees, stream channel improvements, and other measures, are effective in controlling flood damages in small watersheds and in reducing peak flows farther downstream. Such programs involve cooperative efforts by private landowners and local, State, and Federal agencies.

PRESENT SITUATION

Existing Measures

Storage

Storage normally available for flood control within the region amounts to 25 million acre-feet (see table 1). Additional storage, up to nearly 21 million acre-feet, is available in Canada on a forecast basis for control of major floods on the Columbia River. Thus, the total storage available for flood control on either a single-purpose or joint-use basis is nearly 46 million acre-feet. An additional 11.1 million acre-feet reduces flooding in some areas incidental to filling for primary functions of irrigation and power.

Table 1 - Flood Control Storage, 1970, Columbia-North Pacific Region 1/

Storage in 1,000 Acre-Feet						
Subregion	Allocated Primary	Flood Control Joint Use	Incidental		Totals	Usable for Control of Columbia R. Floods
			Major Res.	Farm Pond and Small Res.		
Canada						20,900
1		10,319	335	24.0	10,678	10,552
2		5,232	24	21.0	5,276	5,232
3		-	1,071	4.5	1,075	-
4	10	1,716	3,108	51.0	4,883	1,600
5	97	2,270	2,120	97.0	4,584	2,783
6	-	2,000	-	11.0	2,011	2,000
7	8	577	471	38.9	1,094	500
8	100	260	1,850	3.3	2,213	-
9	-	1,703	-	17.7	1,720	-
10	-	65	-	9.7	74	-
11	106	226	1,719	7.0	2,058	-
12	-	-	-	155.3	155	-
TOTAL	321	24,368	10,698	440.8	35,821	43,567

1/ Includes projects under construction.

Local Protection Projects

The present status of local protection projects is not readily summarized. The subregion chapters variously list nearly 1,800 miles of levees and 3,500 miles of stream channel improvement and stabilization and over 3,000 miles of bank protection (table 2). The projects range from on-farm creeks where material has been taken from the channel and thrown on the banks and the work is counted as both a levee and a channel improvement, to massive levees 25 to 30 feet high designed to withstand the spring and summer freshets on the Columbia River that may last from 2 to 8 weeks. The degree of protection is equally variable. Some minor levees are overtopped almost every year while others

effectively protect urban areas against floods as infrequent as once in a hundred years.

Table 2 - Summary, Local Protection Projects, 1970
Columbia-North Pacific Region

<u>Subregion</u>	<u>Levees miles</u>	<u>Channel Improvement & Stabilization miles</u>	<u>Bank Protection miles</u>
1	161	1,168	488
2	20	203	205
3	64	128	-
4	171	119	131
5	48	192	1,042
6	29	436	407
7	72	366	106
8	449	100	176
9	-	368	115
10	202	383	129
11	578	-	203
12	-	-	20
TOTAL	1,794	3,463	3,022

Land Treatment

Land treatment measures considered effective in reducing peak flows, increasing soil-water infiltration, and controlling erosion which are practiced in significant amounts in this region are listed in table 3. Additional details of these and other measures less significant to flood control are given in the sub-region chapters of this appendix and in Appendix VIII, Land Measures and Watershed Protection.

Table 3 - Significant Land Treatment Practices, 1970
Columbia-North Pacific Region

Cropland Practices	
Effective Combination of Practices	9,533,000 acres
Conservation Cropping Systems	7,247,000 acres
Crop Residue Use	7,130,000 acres
Land Shaping and Irrigation Water Management	2,253,000 acres
Drainage Ditches, Diversions, & Terraces	15,574 miles
Forest Land Practices	
Erosion Control Works	217,000 acres
Road & Trail Rehabilitation	13,723 miles
Rangeland Practices	
Grass Seeding	2,964,000 acres
Brush and Weed Control	2,931,000 acres
Grazing Control	22,193,000 acres

Insurance

Flood insurance is another complement to preventive and protective measures recently made available by Congress. The National Flood Insurance Act, passed in 1968 (4), authorizes subsidies to make flood insurance available at reasonable rates in those areas where official legislative or executive actions have been taken to recognize a public need for flood insurance. To qualify an area for insurance under the act, local agencies must establish a satisfactory system of land use controls which will guide development away from flood-prone areas, assist in reducing damage by floods, and improve the long-range management and use of flood-prone areas. Official action has been initiated (Dec. 1970) by the cities of Springfield, Oregon, and Richland, Washington, and for unincorporated areas in Jackson, Josephine, and Lane Counties, Oregon, and Snohomish County, Washington. Insurance coverage under the Act may be issued in those areas. Requests for insurance approval in other areas are pending. To be eligible for subsidies under the 1968 Act, requests to have areas designated as eligible must be initiated prior to the end of calendar year 1971.

Accomplishments of Existing Improvements

The effectiveness of existing projects in controlling floods and flood damages is described in the subregion chapters. It is estimated that all major projects in the region reduce the total average annual damages from flooding by \$70 million. Comprehensive action programs on 33 watersheds have reduced the extent of flooding on 71,000 acres and average annual damages by \$1.3 million dollars. These damage reduction estimates are not a summary of damage reductions listed in the subregion chapters because in many areas project effects are described in terms of lowered flood stages or reduced frequency of flooding. Neither are the estimates all inclusive. They do not include damage reductions by small levees that convert tidal flats into usable pasturelands, by the hundreds of miles of channel improvements on small tributary streams, or by land treatment practices in other than the 33 specific watersheds.

Remaining Flood Problems

The evaluation of remaining flood problems reflects 1967 economic development and price levels and 1970 flood control structural development including projects under construction as of January 1, 1970. Exceptions occur in Subregions 9 and 11, where the data came from the respective Type II studies.

All of the subregions experience problems in varying degrees of severity. The most serious remaining problems are encountered on several of the larger streams flowing into Puget Sound and in the Rogue and Umpqua Basins of Subregion 10. Serious problems occurred in the Willamette Basin and along the Columbia River below Bonneville Dam but the more serious aspects of these problems have been relieved by existing and under construction structural measures. Remaining problems are summarized in table 4. A brief description of the problems in each subregion follows.

Subregion 1

Major problem areas in Subregion 1 are along the Flathead River from Kalispell to Flathead Lake; at Deer Lodge and Missoula on the Clark Fork; at Kellogg, Smelterville, and Wallace on the Coeur d'Alene; and around Pend Oreille and Coeur d'Alene Lakes. Minor problems occur in scattered rural areas on major streams and tributaries.

Subregion 2

The Okanogan River floods the growing communities of Omak, Okanogan, and Oroville and an important highway and railroad and causes some agricultural damage annually. Damages also occur along the Wenatchee River, Crab Creek, and Esquatzel Coulee and in the city of Wenatchee from several side canyons.

Subregion 3

Major problem areas in Subregion 3 are along the Yakima River at South Cle Elum, Thorp, Ellensburg, Selah, and Yakima and at Naches on the Naches River.

Subregion 4

Specific problem areas in Subregion 4 are on the Jackson Hole and the Heise to American Falls reaches of the Snake River, on Henrys Fork and Teton Rivers, in the Willow-Sand Creek Basin, on Blackfoot and Portneuf Rivers and on Lyons Creeks (also known as Lyman Creek). Some damages occur on several other tributaries. Damages occur to both urban and rural areas.

Subregion 5

Flood damages occur along every important tributary in Subregion 5 but not along the Snake River. Damages are principally agricultural and result from inundation and bank erosion.

Subregion 6

Flood damages in the Clearwater, Grande Ronde, and Palouse River basins account for more than 90 percent of the total damages in Subregion 6. Principal problem areas are along the Clearwater downstream from the confluence with the Selway, on the Grande Ronde at La Grande and Elgin and at Moscow and Pullman in the Palouse Basin.

Subregion 7

The possibilities of flash floods on Willow Creek at Heppner and Zintel Canyon at Kennewick are the most pressing problems in Subregion 7 at this time. Damages are widely scattered in most other parts of the subregion and it is problematical

whether any specific area will require structural protection prior to 2020.

Subregion 8

Levees and channel improvements along with upstream storage on the Columbia River and major tributaries protect 110,000 acres in Subregion 8 at this time. Additional drainage facilities, levee improvements, or both are needed on nearly one-third of these areas. An additional 60,000 acres in the flood plain has no levee protection.

Subregion 9

Major problem areas in Subregion 9 occur in and adjacent to the cities of Springfield, Eugene, Corvallis, Albany, Salem, and Portland. Suburban areas around these cities are growing and compounding the flood problems.

Subregion 10

The most significant problems in Subregion 10 are along the larger streams such as the Rogue, Umpqua, Coquille, and Chehalis. Both urban and rural areas are affected. Beach and estuarine erosion also causes problems.

Subregion 11

Most of the agricultural lands and many suburban and industrial areas along the east side of Puget Sound have inadequate protection. Problems are especially acute in the Nooksack, Skagit, Snohomish, and Green-Dumwamish River Basins. Further compounding of the problems is expected in view of the anticipated growth in the subregion.

Subregion 12

Minor flood damages occur along the Silvies and Chewaucan Rivers.

The remaining flood problems are described in more detail in the subregion chapters. The most significant fact about the remaining flood problems is that almost without exception the

Table 4 - Remaining Flood Problems 1/, Columbia-Nort

Sub-region	Areas Flooded <u>2/</u> 1,000 Acres			Average Annual Damages				
	Major Streams	Minor Streams	Total	Major Streams			Minor Stream	
				Rural	Urban	Total	Rural	Urban
1	129	186	315	531	574	1,105	1,466	118
2	32	115	147	265	1,424	1,689	2,403	180
3	39	86	125	442	274	716	905	145
4	204	380	584	756	319	1,075	5,783	975
5	70	125	195	518	224	742	1,738	193
6	64	178	242	436	509	945	3,489	158
7	42	123	165	748	319	1,067	2,322	170
8	106	100	206	1,233	164	1,397	1,402	351
9	513	177	690	553 <u>3/</u>	2,581 <u>3/</u>	3,134 <u>3/</u>	808 <u>3/</u>	292 <u>3/</u>
10	140	297	437	3,051	3,894	6,945	2,442	840
11	278 <u>4/</u>	357 <u>4/</u>	635 <u>4/</u>	2,960 <u>4/</u>	3,832 <u>4/</u>	7,122 <u>4/5/</u>	7,833 <u>4/</u>	989 <u>4/</u>
12	-	184	184	406	262	668	785	16
TOTAL	1,617	2,308	3,925	11,899	14,376	26,605 <u>5/</u>	31,376	4,427

1/ 1967 prices and economic development except as noted, 1970 structural protection including p

2/ Plus scattered small areas.

3/ Data from Willamette Basin Comprehensive (2), 1965 price levels.

4/ Data from PSAW (1), 1966 price levels.

5/ Includes \$330,000 not segregated between urban and rural.

e 4 - Remaining Flood Problems 1/, Columbia-North Pacific Region

Average Annual Damages \$1,000									
Major Streams		Minor Streams			Bank Erosion				
Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Total	
574	1,105	1,466	118	1,584	334	0	334	3,023	
1,424	1,689	2,403	180	2,583	282	0	282	4,554	
274	716	905	145	1,050	52	0	52	1,818	
319	1,075	5,783	975	6,758	766	44	810	8,643	
224	742	1,738	193	1,931	1,045	55	1,100	3,773	
509	945	3,489	158	3,647	696	44	740	5,332	
319	1,067	2,322	170	2,492	1,068	76	1,144	4,703	
164	1,397	1,402	351	1,753	456	153	609	3,759	
<u>3/</u> 2,581 <u>3/</u>	<u>3/</u> 3,134 <u>3/</u>	808 <u>3/</u>	292 <u>3/</u>	1,100 <u>3/</u>	1,039 <u>3/</u>	127 <u>3/</u>	1,166 <u>3/</u>	5,400 <u>3/</u>	
3,894	6,945	2,442	840	3,282	834	208	1,042	11,269	
<u>4/</u> 3,832 <u>4/</u>	<u>4/</u> 7,122 <u>4/5/</u>	7,833 <u>4/</u>	989 <u>4/</u>	8,822 <u>4/</u>	115 <u>4/</u>	0 <u>4/</u>	115 <u>4/</u>	16,059 <u>4/</u>	
262	668	785	16	801	0	0	0	1,469	
14,376	26,605 <u>5/</u>	31,376	4,427	35,803	6,687	707	7,394	69,802	

as noted, 1970 structural protection including projects under construction.

, 1965 price levels.

an and rural.

2

areas which are presently protected need further protection. Three factors contribute to this problem. The first is that the flood plain lands are more productive, more easily developed, and more readily irrigated than adjacent higher, flood-free lands and as the region develops will be needed for more intensive crop usages. The second is that communities are located near the more productive farmlands and in many cases are on the banks of the streams. Growth of these communities is natural and occurs regardless of any flood hazard. The third is that many of the previous flood control works have stimulated growth in the protected areas which has increased the damage potential and hence the need for further flood protection. Flood plain areas and average annual damages considering 1967 price levels and economic development and 1970 structural protection are shown in table 4.

FUTURE DAMAGES

The full extent of the flood problem and an assessment of requirements for future flood control requires consideration of future regional development and the flood damages that will be incurred, taking into account the extent to which the flood plains in the region will share in this development.

Economic Parameters of Growth

In urban areas, flood damages are comprised mainly of damages to property, real and personal, and in agricultural areas, principal damages are to crops, livestock, and agricultural equipment. An estimate of the magnitude of future flood damages requires projections of trends of development and economic activity that affect flood damages. Economic parameters most directly related to the amount and value of property developments are population and per capita income. Projected trends in agricultural productivity are pertinent to evaluation of the magnitude of future crop damages.

Following trends of the past years, the population of the Columbia-North Pacific Region is projected to grow for the next 50-years at a rate somewhat faster than the entire United States. However, deviations from the national rates are projected to diminish by 2020. The annual rate of growth in population from 1960 to 2020 is projected at 1.42 percent, which compares with the projected national average of 1.32 percent.

Population growth by subregion is expected to vary considerably. The Puget Sound and Willamette Subregions, which have the larger urban centers, are expected to grow faster than the remainder of the region. Population increases in the subregions which are predominately agricultural will take place in urban centers but not in the rural areas.

Per capita income in the Columbia-North Pacific Region was slightly above the national average in 1962 but is expected to increase significantly less than the national average from 1960 to 1980. Thereafter it will increase at about the national rate. Growth in total personal income in the region, reflecting the higher projected population growth, will be slightly above the national average. Table 5 shows the projected growth in population, per capita income and total personal income for each subregion, the region, and the Nation.

The production per acre of crops grown in flood plain areas is expected to increase at about 1.5 to 2.5 percent per year depending on the type of crop and local conditions. This increase will result from more intensive cultivation, improved varieties, and increased irrigation and use of fertilizer. While crop production is projected to increase, agricultural employment is projected to decline.

Development in most flood plain areas is expected to follow the patterns of the recent past and areas that are presently agricultural are expected to remain without radical change in cropping

Table 5 - Projected Average Annual Growth Rates, Columbia-North Pacific
1960-2020

<u>Subregion</u>	<u>Population</u>	<u>Per Capita Income</u>	<u>Total Personal Income</u>
1	1.18	3.02	4.24
2	1.36	2.96	4.36
3	1.12	2.94	4.09
4	1.25	2.95	4.24
5	1.30	3.04	4.38
6	0.93	3.09	4.04
7	1.19	3.01	4.24
8	1.11	3.03	4.18
9	1.70	2.90	4.65
10	1.09	2.94	4.06
11	1.54	2.74	4.32
12	0.84	2.89	3.75
Columbia-North Pacific Reg	1.42	2.89	4.35
Entire U.S.	1.32	2.97	4.33

Source: Economic Work Group.

practices. However, increasing suburban development is expected in areas adjacent to major urban centers, especially throughout the entire length of the Puget Sound-Willamette Valley Trough. Another change significant of flood problems that is occurring and is expected to continue is the construction of resorts and vacation homes in coastal areas and along mountain streams.

Projections of Flood Damages

Future average annual damages in Subregions 9 and 11 were taken from the respective type II studies (2, 1). Future damages in the other subregions were projected as follows:

Urban

It was assumed that most flood plains in urbanized areas would exhibit growth characteristics similar to the subregions in which they are located. Projected annual growth rates of population and per capita income, by subregions, are shown in table 5. These growth rates were used as a guide in projecting future flood damages. However, adjustments were made by time frame to reflect varying rates of growth and by areas where lesser rates of growth were anticipated.

Rural

Rural damages were projected for each flood plain area on the basis of expected productivity of the crops characteristic of the area. Value of rural residential properties would likely increase at a greater rate, based on projected trends in per capita income. Offsetting this increase, however, is an expected decline in the rural population and number of rural residences. Crop losses comprise the bulk of total rural damages and application of projected trends in crop productivity to the overall category provides a sufficiently accurate basis for determining total regional and subregional damages.

Total Damages

More than 3.9 million acres of flood plains have been identified comprising 1.6 million acres flooded by major streams and 2.3 million acres by minor streams, see table 4. Average annual flood damages in these areas total nearly \$70 million and are projected to increase to \$93 million by 1980, \$138 million by 2000, and \$219 million by 2020 (see table 6). These projected damages assume that no further flood protection is provided and that developments in flood plain areas are allowed to proceed as in the past without constraint. Much of the future damages could be prevented by the structural and nonstructural measures discussed herein including storage, levees, channel improvements, flood forecasting, flood plain regulations, land treatment, and other measures.

Table 6 - Projected Average Annual Flood Damages,
Columbia-North Pacific Region

Subregion	\$1,000 1967 Price Levels			
	1967	1980	2000	2020
1	3,020	3,840	5,300	8,000
2	4,550	6,490	10,400	18,300
3	1,820	2,390	3,300	5,000
4	8,640	11,370	13,900	17,200
5	3,770	4,690	5,900	7,700
6	5,330	6,840	8,900	11,700
7	4,700	5,810	7,600	10,000
8	3,760	4,770	7,100	10,800
9	5,400 ^{1/}	7,100 ^{1/}	11,100 ^{1/}	20,300 ^{1/}
10	11,270	15,130	24,500	41,200
11	16,060 ^{2/}	22,670 ^{2/}	37,200 ^{2/}	64,100 ^{2/}
12	1,470	1,980	3,200	4,900
TOTAL	69,790	93,080	138,400	219,200

^{1/} Data from Willamette Type II Study, Flood Control Appendix, 1965 data and price levels.

^{2/} Data from Puget Sound Type II Study, Flood Control Appendix, 1966 data and price levels.

MEASURES TO SATISFY FUTURE NEEDS

Objectives

The objective of flood control for the Columbia-North Pacific Region should be to attain proper use and protection of all flood plain areas consistent with the needs of the region, the potential of each flood plain area, availability of alternative areas, and practicability of providing protection. Planning to meet such an objective must incorporate overall flood plain management techniques that recognize that potential damages can be reduced in part by controlled utilization of the flood plains as well as by structural measures. It is particularly important to restrict economic development in areas where structural protection is not practicable or warranted.

In general, when structural measures are used they should, as an ultimate objective, provide protection against a Standard Project Flood. A Standard Project Flood (abbreviated S.P.F.) is a hypothetical flood representing the most critical flood runoff volume and peak discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic for the hydrologic region involved, excluding extremely rare combinations. Economic considerations, including the best use of public funds and physical limitations of each drainage basin, generally dictate provision of a lesser degree of protection. As a minimum 100-year protection should be provided to urban and suburban areas, and floods that exceed the protection provided should not pose an undue threat to human life. Agricultural lands may be protected to a lesser degree but should have 25-year protection for areas in which homes are located.

Structural Measures

Storage

Economic considerations which prevent attainment of the above flood control objectives do not rule out provision of some structural measures to reduce damages. Storage of floodflows will continue to be one of the most desirable means of reducing damages. It not only prevents the overflow of flood plain land adjacent to the streams, but also prevents destruction within the stream channels. Further, joint use of storage is generally feasible in the region and makes additional water available for other uses during low flow seasons.

Studies for this report have been made to determine the volume of storage required to accomplish the flood control objectives set forth herein at certain critical locations on the larger streams of the region. The results of these studies are contained in the subregion sections. However, since the indicated storage in each subregion is neither the amount of storage needed to control all flooding in the subregion, the amount that could reasonably be justified under current criteria, nor the amount for which suitable storage sites are available, no useful purpose would be served by assembling a summary total.

Levees and Channels

Levees and channels can supplement the protection provided by storage. In the subregion chapters levee projects totaling nearly 900 miles and channel projects totaling nearly 650 miles are described to protect critical areas. The following table summarizes these projects.

Table 7 - Needed Levee and Channel Improvements, Major Streams
Columbia-North Pacific Region

<u>Subregion</u>	<u>Levees, miles</u>	<u>Channel Improvement, miles</u>
1	90	8
2	30	58
3	39	0
4	60	45
5	105	98
6	42	33
7	56	55
8	125	57
9	0	165
10	187	0
11	148	53
12	0	0
Regional Totals	882	572

Other Structural Measures

In addition to the structures provided for flood protection on major streams, structures are also required on minor streams to more fully control floodflows. These comprise channel improvements, dikes and levees, channel stabilization and small reservoirs. A complete discussion of these needed structures can be found in Appendix VIII, Land Measures and Watershed Protection. A summary of the measures is given in table 8.

Table 8 - Needed Structural Measures, Minor Streams and Upstream Areas,
Columbia-North Pacific Region

Subregion	Channel Improvement miles	Dikes Levees miles	Streambank Protection miles	Channel Stabilization miles	Small Storages number	Other number
1	1,500	360	3,600	35	1,900	900
2	550	10	7,035	5	400	2,200
3	450	50	260	120	2,700	340
4	610	100	5,420	60	9,500	2,000
5	2,000	1,250	6,850	500	28,900	1,800
6	1,000	50	900	10	9,200	360
7	4,900	560	1,900	120	7,700	900
8	340	70	630	35	500	50
9	780	60	365	-	3,200	0
10	5,000	1,300	1,600	50	3,600	625
11	1,050	150	700	20	3,600	-
12	390	360	920	10	8,000	25
TOTAL	18,570	4,230	30,180	965	79,200	9,200

Nonstructural Measures

Since complete flood control by structural means will be neither possible nor desirable, some nonstructural measures will be required. Important nonstructural measures that will be effective to help meet the needs include (1) land use regulation, (2) flood forecasting, (3) flood proofing and (4) land treatment practices.

Land Use Regulation

An effective program of land use regulations is urgently needed throughout the region to prevent development in areas that cannot be feasibly protected because of physical limitations and to control development in areas having only partial protection. The flood plain information program authorized by Congress provides a vehicle for disseminating information to local interests as to flood hazards, the extent to which developments should be limited, and the types of regulations required. Flood plain information reports as a basis for zoning and flood proofing regulations have been prepared for 33 localities as shown on figure 4. Reports on additional areas are being prepared. Flood hazard areas have also been delineated on special issues of topographic maps published by the Geological Survey. Approximately 90 such maps on 7-1/2 and 15-minute quadrangles have been prepared.

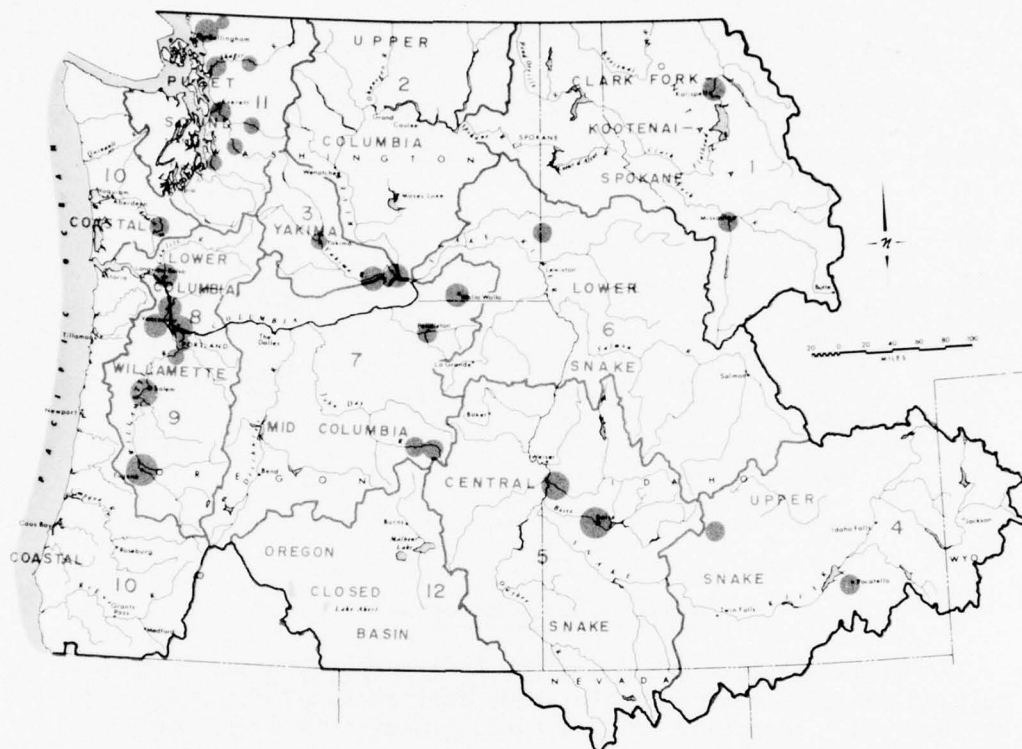


Figure 4. Localities with Completed Flood Plain Information Reports.

Flood Forecasting

Flood forecasting and preventive measures that can be instituted as a result of the forecasts provide a useful supplement to structural and nonstructural controls. The Columbia-North Pacific Region has an effective flood forecasting organization, the Cooperative Columbia River Forecasting Unit.

By agreement between the National Weather Service and the Corps of Engineers, the hydrological resource talents and computer facilities of the North Pacific Division of the Corps of Engineers and the Portland River Forecast Center of the National Weather Service have been combined into the Cooperative Columbia River Forecasting Unit. The Cooperative Columbia River Forecasting Unit uses input data from all available sources but relies primarily on snow survey data provided by the Soil Conservation Service and others, streamflow data furnished by the Geological Survey and other agencies which maintain stream gages, and weather data by the National Weather Service. These arrangements were made to

provide better control of the major reservoirs in the Columbia River Basin for flood control, power, irrigation, and other uses.

Streamflow forecasts including flood warnings are routinely made for 122 locations throughout the region. Additional forecast points are added as requirements are made known. Forecasts are made to cover long-, medium- and short-range periods. Long-range forecasts are concerned with the volume of runoff in the major streams several months in advance on a seasonal basis (usually for the period April through September). Medium-range forecasts cover periods from 10 days to 1 month. Short-range forecasts cover the chronological distribution of flows for periods 2 to 10 days following the date of forecast. Medium- and short-range forecasts are made daily, compared with actual flows, and disseminated as needed to the public and using agencies.

Foresight Operations

The long-range forecasts provide the basis for advance preparation or foresight operations (a pre-flood fight technique) which are very effective in averting potential losses when coping with spring snowmelt floods. Maximum use can be made of all available storage space and protective systems can be strengthened at points of known weaknesses. Moreover, sufficient time generally is available to allow much damageable material to be removed from the potential flood zone or stored at an elevation above the expected flood stage. Other items that cannot be removed can be protected.

"Foresight operations" have only slight applicability in the rain flood belt west of the Cascade Range and during the winter floods characteristic of the lower elevation areas east of the range. In these areas the flood potential exists every winter season and actual flood situations develop with such rapidity that significant advance preparation for any specific situation cannot be undertaken. Forecasting, however, generally permits limited emergency actions to reduce the impact of flooding.

Flood Fight

Another activity useful in decreasing losses and human suffering accompanying floods is the so-called flood fight. A flood fight comprises all actions taken during a flood emergency to reduce losses and, following the flood, to restore essential facilities and prevent compounded damages by subsequent high water. During a flood, levees or other embankments functioning as levees may be raised or strengthened, seepages contained, and debris or ice accumulations broken up. Where the situation necessitates,

people and some property may be evacuated from the path of the floodwaters. Each occurrence prevents different situations which require different actions to minimize losses. Post flood fight activities include channel clearing, repair of damaged flood control works, and restoration of essential transportation, communication, and sanitary facilities.

A flood fight is generally the responsibility of a local government but includes both public and private efforts. If a flood exhausts the local resources, the Corps of Engineers is empowered, on request, to assist in the flood fight or assume all further responsibility. The Corps also assists in post-flood recovery by repair or restoration of flood control works damaged or destroyed by floods. If a flood is of sufficient magnitude to be declared a National disaster, the flood fight activities are coordinated by the Regional Director of the Office of Emergency Preparedness.

Insurance

Nearly 200 localities throughout the region have flood problems such that individual property owners would benefit from the flood insurance program. If any of these areas where future needs are met by zoning rather than structural measures, insurance would be needed for financial protection to existing development.

Watershed Land Treatment Practices

Needed land treatment practices to retard surface runoff and reduce the amount of sediment load reaching the streams are described in Appendix VIII, Land Measures and Watershed Protection. An additional 32 million acres will require treatment by 2020 to reduce and control erosion. Another 3.3 million acres will require the installation of drainage structures of various types. Further details are contained in the subregional sections of this appendix and in Appendix VIII.

Comprehensive Watershed Treatment Programs

Comprehensive programs involving the cooperative efforts of private landowners, local, Federal and State agencies are needed on 222 watersheds by 1980, 336 watersheds by 2000, and 350 watersheds by 2020.

Subregion Summaries

Measures that would reduce present and future damages in each subregion are summarized in the following paragraphs. Measures such as structures on minor tributaries and land treatment practices that generally are applicable in all areas are omitted from the summaries. Additional details are included in the subregion chapters.

Subregion 1 Storage could be used to control flooding in the Clark Fork-Pend Oreille and Spokane Basins, and sites exist that are physically suitable. However, low overall economic values and possible conflicts with other interests preclude development at this time. Levees and channel improvements offer feasible alternatives for protecting critical locations as described in the subregional chapter. A particular need at this time is the improvement of the channel at the outlet of Flathead Lake so that higher flows may be passed and the lake surface elevation more nearly stabilized. Flood plain use regulations are immediately needed for critical areas along the Flathead, Clark Fork, and Spokane Rivers.

Subregion 2 Storage would have a significant effect on local flood damages along the Okanogan River, and Crab Creek, and a minor effect along other streams. Potential sites have been identified which would provide more than 3 million acre-feet of storage. A reservoir on the Similkameen, which would control floods on the Okanogan, would extend into Canada. Levees and channel improvements that would control flooding on the Okanogan, Wenatchee, and Colville Rivers, Crab Creek, Esquatzel Coulee, and Canyons 1 and 2 at Wenatchee, are described in the subregion chapter. Flood plain use regulation would help control urban expansion that would be susceptible to future damages.

Subregion 3 Flood protection to the 100-year frequency level would require about 300,000 acre-feet of additional storage selectively located. Eight storage sites are known in which the necessary storage might be obtained. Local protection projects would control flooding at South Cle Elum, and near Ellensburg and Toppenish. Land use regulations are needed to control development on flood-prone lands.

Subregion 4 Flood control could be achieved by storage on the Snake River and practically all tributaries in Subregion 4. However, it is improbable that complete control would ever be achieved by storage and additional local protection projects could be used to further reduce damages at the lower Jackson Hole area and along the lower reaches of Henrys Fork and Portneuf River. Levees alone would protect areas around Mud Lake and lower Camas

Creek and many other isolated areas throughout the subregion. Land use regulations would assist in controlling future developments subject to flood damage.

Subregion 5 Storage would control flash floods caused by convective storms on hillside drainages at Boise and other towns in Subregion 5 and would be of benefit on all major tributaries. Levees and channel improvements would protect areas along the Boise, Payette, and Weiser Rivers, and on Succor Creek. Land-use regulations are urgently needed in the Boise area and should also be adopted in the Weiser and Malheur River Basins.

Subregion 6 Properly located storage amounting to 3.8 million acre-feet would provide a high degree of protection for the flood-prone lands. Levee and channel improvement projects are required in combination with or in lieu of storage. Specific problem areas include Salmon, Wallowa, Clearwater, Tucannon and Palouse Rivers and Asotin Creek. Land use regulations would control developments in areas subject to flood hazards.

Subregion 7 The amounts of storage to attain specified flood control objectives on the Walla Walla, Umatilla, and John Day basins would total 626,000 acre-feet. Levees and channel improvements would prevent flood damages in the Umatilla, Touchet, John Day and Crooked River Basins and on Willow Creek and Zintel Canyon. Land use regulations should be adopted to control development in the flood plains around the cities of Pendleton, Kennewick, and Walla Walla.

Subregion 8 Further significant reduction of floodflows would require large blocks of upstream storage but only major floods would be affected. The Cowlitz River has the greatest need for additional storage within the subregion. Improvements to existing levees and additional drainage facilities would allow higher land use and new levees are needed along the Columbia and upper Cowlitz Rivers. Some existing levees need bank stabilization works. Land use regulations would control development on flood prone lands.

Subregion 9 Additional storage would be used to increase the degree of flood protection for most of Subregion 9. But on some tributaries, storage will not accomplish the desired objective, and channel and levees will be required. Measures to regulate flood developments are an immediate need throughout the subregion.

Subregion 10 Storage at potential sites in most of the drainages could be used to reduce flooding, but the total of the damages prevented and any possible conservation use of the stored

water would be insufficient to justify development. Moreover, storage reservoirs would generally conflict with environmental interests. On the Chehalis, Rogue, and Umpqua Rivers, however, storage offers a partial solution to the flood problem and would also benefit conservation uses including those of an environmental nature. Generally, levees and channel improvements will be required to solve the flood problem combined with any storage that may be provided. Land use regulations are urgently needed to control development in flood prone areas.

Subregion 11 Storage could be developed at potential sites to control floods of 100-year frequency to nondamaging stages at the principal urban centers but economic and environmental considerations make attainment of such a storage objective impractical. Storage on the Nooksack, Skagit, Snohomish, and Cedar Rivers would partially reduce flood losses, but levees and channel improvements will be also required. Flood plain use regulations are required to control further development in flood prone areas.

Subregion 12 Storage might be developed for flood control and conservation use in the Silvies and Chewaucan River drainages, but levees and channel improvements would also be needed. Developments around the larger communities should be controlled by land use regulations.



LOCATION MAP

1 20-0000000

SUBREGION 1

CLARK FORK - KOOTENAI - SPOKANE

GENERAL

Location and Extent

Subregion 1 occupies an area of 36,361 square miles bounded on the north by Canada, on the east and southeast by the Missouri River Basin across the Continental Divide, on the southwest by the Snake River Basin, and on the west by basins of minor tributaries of the Columbia River in northeastern Washington. The subregion is drained by three major river systems, the Kootenai (Kootenay in Canada), Clark Fork-Pend Oreille, and Spokane. The U. S. portion of the Kootenai River Basin covers 13 percent of the subregion, the Clark-Fork-Pend Oreille 68 percent, and the Spokane 19 percent.

Topography

The subregion is generally rugged and mountainous. Starting at the eastern edge of the Columbia Plateau, the terrain becomes increasingly more rugged toward the east. The mountains generally lie in north-south to NW-SE trending ranges separated by narrow troughs. The major streams form in the troughs and in such areas have built flood plains ranging from a few hundred yards to several miles wide. Where the rivers pass through the ranges, valley bottoms consist of little more than the river channels. Relatively broad valleys with significant flood plains occur along the Kootenai from Bonners Ferry, Idaho, north into Canada; in the Bitterroot Valley, and around Flathead, Pend Oreille, and Coeur d'Alene Lakes. Other flood plains occur in small isolated locations throughout the subregion. Mountain slopes are steep and generally heavily forested. Most agriculture and other developments occupy the valley bottoms.

Climate

The climate is characteristic of the eastern Columbia-North Pacific Region with a continental summer climate and a modified maritime climate during the winter when heavy burdens of moisture

are carried on the prevailing westerly circulation from the Pacific Ocean. Normal annual precipitations vary from less than 15 inches in the lower valleys and protected areas to more than 60 inches in higher mountain regions. In most areas more than 60 percent of the annual precipitation falls as snow between October and April, frequently exceeding 300 inches annually at some higher mountain locations, and snow packs often exceed 150 inches toward the end of the snow season. In the eastern part of the subregion, heavy warm rains in May and June frequently add to the flood runoff from melting snow.

Economic Development

Economically, Subregion 1 encompasses 2 counties in Washington, 5 in Idaho, and 11 in Montana. Approximately 595,000 people lived in the subregion in 1965. Spokane, the principal city with a population of 181,600 in 1960, is an important trade center which serves an extensive inland area. Other important cities and their 1960 populations are: Butte, 27,877; Missoula, 27,090; Coeur d'Alene, 14,291; Anaconda, 12,054; and Kalispell, 10,151.

The economy is primarily supported by agriculture, mining and processing of primary metals, and forest industries. Agriculture, much of which occurs in areas wrested from the flood plain or still subject to flooding, supports about 30 percent of the working force engaged in basic industries.

Dairying and beef raising are the main forms of agriculture. Crops are grown principally for winter livestock feed. However, cash crops are a significant part of agricultural production in the Kootenai Flats area in Idaho, the Clark Fork valley near Plains, Montana, the Flathead Valley from Columbia Falls to Flathead Lake, and the Spokane River Valley.

Mining and the processing of both locally mined and imported minerals provide a substantial portion of the basic employment and income of the subregion. Locally produced minerals include limestone, lead, zinc, copper, silver, and gold. The Butte district in Montana and the Coeur d'Alene in Idaho are leading producers of copper and silver, respectively. Lead and zinc are produced, smelted, and refined at Kellogg, Idaho. Cement is produced at Metaline Falls, Washington. Aluminum is refined at Spokane, Washington, and Columbia Falls, Montana.

The mountainous forest areas with clear fresh-water lakes and streams form an attractive environment for outdoor recreation. Trade and service industries are expanding because of these recreational attractions.

The land transportation system generally follows the river valleys. Interstate Highway 90 crosses the subregion in an east-west direction through Butte, Missoula, and Spokane. U. S. Highway 2 skirts Glacier National Park and also passes through Spokane, but crosses farther north. U. S. Highway 95 runs north and south past Coeur d'Alene and Pend Oreille Lakes and U. S. 93 runs north and south past Flathead Lake and through Missoula and the Bitterroot Valley. Several railroads serve the subregion, and a major rail center is located at Spokane. Portions of these important transportation routes are located in flood plains.

Streams

The general characteristics of the subregion's streams, such as drainage area, average flows and peak flows, are important considerations in presenting the flood problems. Such information is presented in table 9. The stream patterns can be seen on figure 5.

Table 9 - Streamflow Summary, Subregion 1

Stream	Drainage area SM	Gaging Station Location	Drainage area SM	Mean Flow 1/ Cfs	Momentary Flow 2/ Max. Min. Cfs Cfs	
Kootenai (U.S. Portion)	19,300 5,040	Porthill, Idaho	13,700	15,328	125,000	1,380
Pend Oreille (U.S. Portion)	25,960 25,214	Newport, Wash.	24,200	24,457	136,000	1,280
Clark Fork		Below Missoula, Mont.	9,003	5,066	52,800	388
Blackfoot	2,316	Plains, Mont.	19,958	18,328	134,000	3,200
Bitterroot	2,851	Bonner, Mont.	2,290	1,479	19,200	200
St. Regis	364	Darby, Mont.	1,049	3/	11,500	71
Flathead	9,080	St. Regis, Mont.	303	3/	7,740	45
(U.S. Portion)	8,630	Columbia Falls, Mont.	4,464	9,552	176,000	798
Flathead (N.F.) (U.S. Portion)	1,612 963	Columbia Falls, Mont.	1,548	2,894	69,100	198
Middle Fork	1,137	West Glacier, Mont.	1,128	3/	140,000	173
South Fork	1,670	Columbia Falls, Mont.	1,663	3,342	46,200	7.3
Swan River	737	Big Fork, Mont.	671		8,400	193
Spokane River	6,589	Spokane, Wash.	4,290	6,485	49,000	95
Coeur d'Alene	1,488	Cataldo, Idaho	1,220	2,471	67,000	122
St. Joe	1,886	Calder, Idaho	1,030	3/	53,000	91
Hangman Creek	689	Spokane, Wash.	689	3/	20,600	2.3

1/ Regulated value for base period, see Appendix V.

2/ Observed flows for period of record at gaging station.

3/ Not available.

Additional information on streams and streamflows is contained in Appendix V, Water Resources.

Flood Characteristics

Major flooding on the Kootenai River takes place in May or June as the result of melting of a heavy snowpack during an extended period of warm weather. Fed steadily by the snowmelt, floods on the Kootenai persist for as long as 30 days. Flooding in the Clark Fork-Pend Oreille Basin is also a result of snowmelt, occasionally augmented by rainfall. Rainstorms alone do not normally cause floods except in subbasins exposed to local storms of high intensity. A duration of 20 to 30 days is typical of floods in this basin. In contrast to the Kootenai and Clark Fork basins, where major flooding almost invariably occurs with snowmelt in May or June, flooding in the Spokane River Basin may take place either in spring (April-June) or winter (December-January). Duration of flooding is less; streams are not usually out of banks more than a week or 10 days. Flooding in the tributary areas usually occurs during the late spring or early summer from the heavy snowpack melting (often accompanied by rainfall) which causes the flooding on the major streams.

HISTORY OF FLOODING

Major floods on various streams of the subregion are listed in table 10. Discharges shown were measured at the time of the flood or estimated from high watermarks when streamflow records, table 9, were not available. Damages given are those which would occur if the flood were repeated with present day development and price levels considering existing local protective measures but not existing storage.

Kootenai River Basin

The extent of damages in the Kootenai River has depended on the number of levee failures, but most floods have involved a considerable acreage of wheatlands and part of the town of Bonners Ferry. In 1956 levees failed in 14 diking districts and 17,000 acres were flooded. Railroads and U. S. Highway 95 were out of service for a week. Although Bonners Ferry was not flooded, 15 percent of the population was evacuated, and pumping was required to remove seepage. Minor damages occurred at Troy, Montana.

Clark Fork-Pend Oreille Basin

There are four principal areas on the main Clark River where damages have occurred during flooding. These are (1) the entire reach upstream from the mouth of the Blackfoot River, (2)

the city of Missoula and the adjacent area called Orchard Homes, (3) the reach from the mouth of the Bitterroot River to Frenchtown and (4) the reach from Plains to Eddy. Residences, business establishments, irrigation structures, farmlands, streets, roads, and railroads have been damaged. Floods are of considerable duration on the Clark Fork; for example, in 1948 it was out of banks for 20 days at Missoula. (7)

On the Pend Oreille River, damages have been largely to grain crops and pastureland with some buildings and roads affected around Pend Oreille Lake.

On the Bitterroot River the last four major floods have each inundated 19,000 acres of pasture and woodland. Damages occurred to buildings in Stevensville and Hamilton, and to roads, bridges, and levees. The 1899 flood was somewhat larger, but developments were fewer.

Table 10 - Major Floods, Subregion 1 ^{1/}

Stream	Date	Discharge (cfs)	Measured at	Damages for stated discharge with 1967 prices and development
Kootenai	Jun 1894	160,000		\$13,000,000
	May 1948	139,000	Bonniers ^{2/}	9,280,000
	Jun 1950	90,000	Ferry	2,570,000
	May 1954	132,000		2,730,000
	May 1956	127,000		7,456,000
	May 1961	^{3/}		4,166,000
Clark Fork	Jun 1894	42,000	Above Missoula	663,000
	Jun 1899	36,400		^{3/}
	May 1908	51,000	(Note:	^{3/}
	May 1913	30,800	Discharge at	^{3/}
	May 1917	25,500	Plains about	-
	Jun 1933	21,600	4 times as	24,000
	May 1948	31,500	great)	316,000
	Jun 1964	31,700		^{3/}
Pend Oreille	Jun 1894	200,000	Newport	6,834,000
	Jun 1933	135,000		348,000
	Jun 1948	162,000		2,765,000
	Jun 1956	130,500		332,000
Bitterroot	Jun 1899	37,440	Mouth	^{3/}
	May 1948	11,300	Darby	440,000
	May 1956	10,500		56,000
	May 1957	11,500		^{3/}
	Jun 1964	9,450		53,000
St. Regis	Dec 1933	14,000	St. Regis	574,000
	May 1938	12,000		214,000
	May 1948	-		120,000
	May 1954	11,000		105,000
Flathead	Jun 1894	142,000	Columbia	3,347,000
	Jun 1933	91,200	Falls	1,838,000
	Jun 1948	102,000		1,511,000
	Jun 1964	176,000		14,000,000
Swan	May 1928	7,820	Bigfork	135,000
	Jun 1933	8,820		155,000
	May 1948	8,400		160,000
	Jun 1964	8,100		147,000
Calispell Creek	Jun 1948	El. 2055	Mouth	^{3/}
	Jun 1951	El. 2040.7		^{3/}
	May 1952	El. 2040.6		^{3/}
	Jun 1956	El. 2042.9		^{3/}
Coeur d'Alene	Dec 1933	67,000	Cataldo	2,219,000
	Apr 1938	46,300		258,000
	Dec 1946	36,000		121,000
	Dec 1964	47,200		270,000
Spokane	May 1894	49,000	Spokane	743,000
	May 1917	41,900		47,000
	Dec 1933	47,800		504,000
Placer Creek	Dec 1933	2,200	Wallace	1,097,000
	Dec 1964	1,700		890,000
St. Joe	Dec 1933	53,000	Calder	95,000
	Apr 1938	46,000		85,000
	May 1956	20,600		-
	Dec 1956	30,500		45,000

^{1/} Includes historical floods not shown in table 9.^{2/} Stages at Bonniers Ferry were: 1894-34.2, 1948-35.3, 1950-34.0, 1954-35.6, 1956-37.1. Zero damage stage is 27.0. Stages have increased with construction of levees.^{3/} Data not available.

The St. Regis River experienced floods of the same general magnitude in 1933, 1938, and 1954. The 1933 and 1938 floods caused extensive damage to railroad lines and U. S. Highway 10, but subsequent corrective measures prevented similar damage in 1954. Portions of the towns of Saltese and St. Regis were inundated each time.

On the Flathead River each of the four major floods shown in table 10 inundated a large part of the 32,000 acres in the flood plain. Damages occurred to grain and pastureland, roads, bridges, farm buildings, and residential and commercial property in urban areas at Columbia Falls, Kalispell, Somers, Bigfork, and Polson. The disastrous flood of June, 1964, caused by intense rainfall on the snowpack, was of extremely rare magnitude. Nearly \$5,500,000 in damages were experienced on the Flathead below the



Area around Kalispell, Montana during June 1964 flood. (USCE)

Middle Fork, and on the Middle Fork even greater damage resulted from massive washouts of railroads, roads, and bridges. Damages there exceeded \$8,500,000. In the course of 24 hours following a weekend of heavy rain, the Flathead at Columbia Falls rose 12 feet and spread out over its banks to a width as great as 4 miles, even though the South Fork was completely controlled by Hungry Horse Reservoir. Five thousand persons were evacuated,

mostly in the vicinity of Columbia Falls and Kalispell; half of these returned to damaged homes. Many county and national forest roads and bridges were washed out, but the enormity of damage to transportation routes was seen chiefly in the confined Middle Fork and its tributary Bear Creek where 15 miles of U. S. Highway 2 and large portions of the main line of the Great Northern Railway were carried away. (13)

Floods in 1928, 1933, 1948, and 1964 on Swan River were all approximately of the same magnitude. Most of the damage was to agricultural land, crops, and buildings; about a third occurred in the vicinity of Swan Lake. In 1964, 53 houses and 840 acres of agricultural land were flooded.

Calispell Creek, a tributary of the Pend Oreille, had major flooding in 1948, 1951, 1952, and 1956. In 1948, the main Pend Oreille levees were overtopped but in the other three floods only interior levees failed. Grain, hay, and pasture fields were damaged.

Lesser damages, not shown in table 10, have occurred on several other tributary streams in the Clark Fork-Pend Oreille basin. In 1964, 32 acres of the town of Deer Lodge, Montana, were inundated by Cottonwood Creek, a tributary of the Clark Fork near its headwaters. Flooding had previously taken place in 1908, 1916, 1917, 1928, and 1948. During the 1964 flood the Little Blackfoot, a tributary of the Clark Fork downstream from Deer Lodge, inundated agricultural lands, roads, and railroads. The Blackfoot River caused damages to residential and commercial property in Lincoln, Montana, and to roads, farms, and irrigation works in 1964. Total basin damages amounted to \$221,000. In 1948, the Stillwater River inundated scattered farm areas. A tributary of the Stillwater, the Whitefish, flooded agricultural lands in 1964.

Spokane River Basin

Floods on the Coeur d'Alene River have affected low-lying lands as far upstream as Wallace on the South Fork. Usually, losses around Coeur d'Alene Lake have been negligible, but in 1933, 25,000 acres were inundated and property in Coeur d'Alene and a number of summer homes and resorts on the lake were damaged. (7)

The St. Joe River is, with its principal tributary, the St. Maries, a larger stream than the Coeur d'Alene, but flood damages have been considerably less. The 1933 flood inundated 5,000 acres. Levees in the vicinity of St. Maries failed in 1948 and 1956.

The flood of 1933 on the Spokane River inundated about 30 acres in the city of Spokane, including industrial, commercial, and residential property along a 4-mile reach of the river. (7)

Several minor tributaries of the Spokane River have experienced significant flooding. Placer Creek, a tributary of South Fork Coeur d'Alene, flooded the town of Wallace in 1896, 1917, 1933, 1938, and 1964. The most extensive damages occurred during the floods of December 1933 and December 1964. (15)

Another tributary of the South Fork, Pine Creek, damaged levees and buildings at Pinehurst in 1964. Hangman Creek, a tributary of the Spokane River at Spokane, inundated 3,500 acres in December 1964, damaging buildings and streets in Spokane and Tekoa, Washington, and Tensed, Idaho, and roads and farmlands. Two-thirds of the damages were in Washington and the remainder in Idaho. (15)

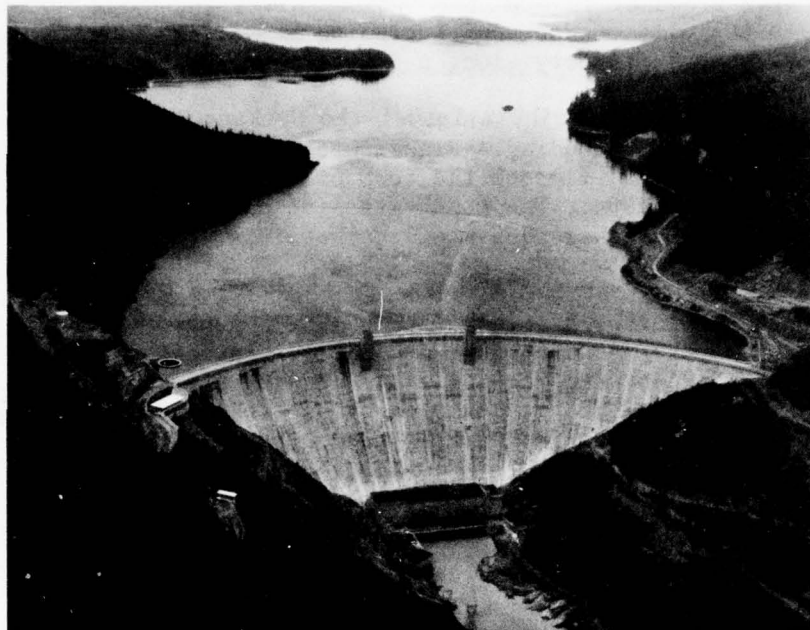
PRESENT STATUS

Existing Measures

Flood Control Storage

Joint-use storage in five major reservoirs in Subregion 1 is regulated for flood control on a forecast basis (table 11). This storage not only reduces flood damages within Subregion 1, but also is effective in control of the lower Columbia River (see table 82). Volumes shown in table 11 are the total joint-use storages in each reservoir; the actual amount available at any particular time is dependent on the seasonal outlook and antecedent conditions. Only limited use can be made of the storage in Flathead Lake. The lake is drawn down each year for power and refilled during the flood season. However, constrictions in the outlet channel between the lake and Kerr Dam limit the outflow and cause the lake to fill during the early part of the flood season. The storage space is thus not available during flood peaks when most needed. The private owners of Noxon Rapids Dam are not required to make space available for flood control but have informally agreed to make 231,000 acre-feet of space available when needed.

Minor Storage Storage in 1,613 farm ponds and small reservoirs on tributary streams amounts to a total of 38,800 acre-feet. Filling of this space for conservation use has an incidental effect on floods principally in the reduction in the frequency of flooding along the tributary streams.



Hungry Horse Dam and Reservoir during June 1964 flood. (USCE)

Table 11 - Flood Control Storage, Subregion 1

<u>Project</u>	<u>River</u>	<u>FC Storage</u> <u>(acre-feet)</u>
Libby (UC)	Kootenai	4,965,000
Hungry Horse	South Fork Flathead	2,982,000
Kerr (Flathead Lake)	Flathead	1,219,000
Noxon Rapids	Clark Fork	231,000
Albeni Falls (Pend Oreille Lake)	Pend Oreille	1,155,000

Levees

Levees have been constructed at many locations on both major and minor streams. Most of the present protection is designed to lessen the damages associated with major flooding (table 12).

Table 12 - Existing Levees, Subregion 1, 1968

<u>Stream</u>	<u>Location</u>	<u>Description</u>
KOOTENAI BASIN		
Kootenai	Kootenai Flats	95 miles of levee protect 32,100 acres along 51 river miles in Idaho, plus town of Bonners Ferry.
CLARK FORK - PEND OREILLE BASIN		
Clark Fork	Missoula, Montana	Six levees totaling 2.5 miles protect 101 acres, comprising residential and commercial property, a sewage treatment plant, and a suburban development.
Clark Fork	Plains, Montana	Two levees on left bank; one across from Plains, one 2 miles upstream.
Pend Oreille	Downstream from Albeni Falls, Idaho	Three leveed diking districts near Cusick. Five or more private levees at other locations.
St. Regis	St. Regis	Levee protects highway and town from St. Regis and Clark Fork Rivers.
Flathead	Kalispell to Flathead Lake	At least 10 levees, mostly across former river channels preventing direct inflow.
Lightning Creek	Clark Fork, Idaho	Levee 1.1 mile long on left bank protects town.
Calispell Creek	Calispell Lake to Pend Oreille River at Cusick	Three levees totaling 5.1 miles.
SPOKANE BASIN		
Coeur d'Alene	Upstream from Coeur d'Alene Lake	Three levees totaling 10.9 miles (partly RR embankment along lower 13 miles of river. Levee 1/2 mile long on right bank at Dudley, Cataldo, Smelterville, and Kellogg on South Fork protected by railroad and highway embankments.
Coeur d'Alene Lake	Coeur d'Alene	Levee 1.4 miles long protects city at intersection of lake and Spokane River.
Pine Creek	Pinehurst	Levee 2.25 miles long on right bank protects Pinehurst. Levee 0.2 miles long on left bank protects town of Pine Creek downstream.
St. Joe	St. Maries	Levee 2.5 miles long on left bank protects town.
St. Joe	Vicinity of St. Maries	16.9 miles of levees in 6 diking districts protect 3,919 acres.
Minor Tribs.	Many locations	23 miles of levees, 1,155 miles of stream channel improvements, 8 miles of channel stabilization, 488 miles of bank protection, and 165 miscellaneous stream structures.

Flood Control Channels

There are four major improved flood control channels in connection with levee and bank protection works. The improved outlet channel from Albeni Falls Reservoir permits better control of lake elevations, thus helping to reduce flood damages on the lakeshore. By spring, the lake is normally drawn down from its maximum controlled elevation of 2,062.5 to 2,051. This provides 1,041,000 acre-feet of storage which, if not filled involuntarily, may be used to control downstream discharges. During high flows on Calispell Creek, this storage is used when possible to reduce Pend Oreille River stages and allow gravity drainage of Calispell Creek.

Cottonwood Creek, a tributary of the Clark Fork, is carried through the town of Deer Lodge by a locally constructed channel having a capacity of 750 cfs. In places, the channel is lined with concrete or timber walls. Placer Creek, a tributary of the South Fork Coeur d'Alene, flows through the town of Wallace in a partly lined channel 20 feet wide, 8 feet deep, and 3,100 feet long. The channel of Hangman Creek has been improved to carry 1,000 cfs for 4.5 miles. The Idaho Highway Department plans to channelize about 1.3 miles of the South Fork Coeur d'Alene River at Wallace during construction of Interstate 90. The channel is designed to carry a 50-year frequency flow. Work is expected to be completed about 1973.

Watershed Protection

More than 1,146,000 acres of cropland have had effective combinations of practices applied which reduce erosion and sedimentation and assist in the reduction of floods. The most effective practices include conservation cropping systems on 556,000 acres, use of crop residue on 491,000 acres, and 42.7 miles of diversions and terraces. Forest land treatment measures to reduce sediment and overland flow include 18,055 acres of erosion control work and 1,105 miles of road and trail rehabilitation. Rangeland practices of particular significance include revegetation for improved cover and soil stabilization and better control and distribution of livestock grazing. About 70,000 acres have been seeded to grass, brush has been controlled on 50,000 acres, 165,000 acres have been treated for weed control, and grazing has been reduced on 507,500 acres. The soils of Subregion 1 are estimated to have a water holding capacity of at least 7,640,000 acre-feet, an average of 4.02 inches over the entire watershed. This storage is effective in retarding runoff to an extent dependent upon land treatment and weather conditions. Additional information on land treatment is given in Appendix VIII, Land Measures and Watershed Protection.

Flood Plain Regulation Program

Local planning agencies are preparing a comprehensive land-use plan for the Missoula area utilizing information from a flood plain information study of the Clark Fork at Missoula. A flood plain information study of the Flathead between Columbia Falls and Kalispell was made in 1969.

Flood Forecasting and Emergency Operation

Estimates of impending peak flood flows or stages and the expected time of occurrence are prepared by the River Forecasting Unit at Portland for the Spokane River District Office. The River District Office in turn calls civil defense and the sheriff's office in each county concerned and advises the national news services. Through these channels, local radio and TV stations are informed. Broadcasting stations in Spokane and Sandpoint, Idaho, are contacted directly by the River District Office. Predictions on flooding of the Kootenai are given by the River District Office to the Boundary County, Idaho, flood coordinator, who alerts local interested parties.

In addition to these channels of information, the Corps of Engineers in Seattle receives flood forecasts directly from the Portland River Forecasting Unit for the benefit of flood engineers assigned to specific areas for flood emergencies (table 13).

Table 13 - Flood Emergency Areas, Subregion 1

Area	Gage	Zero Damage		Local Contact
		Stage ft.	Flow cfs	
Kootenai	Kootenai at Libby	18.1	95,000	Civ. Def. Director, Lincoln Co. Flood Coordinator, Boundary Co.
	Kootenai at Bonners Ferry	27.0	-	
Upper Clark Fork	Blackfoot near Ovando	-	-	Civ. Def. Director, Powell Co. Commissioners (Chairman), Granite Co.
	Clark Fork above Missoula	9.5	18,200	
	Clark Fork above Missoula	9.5	18,200	Civ. Def. Director, Missoula Co.
	Clark Fork below Missoula	-	-	
	Bitterroot near Darby	-	-	Road Superintendent, Ravalli Co.
Upper Flathead	Flathead at Columbia Falls	13.0	48,000	Flood Coordinator, Flathead Co.
	Flathead Lake at Somers	93.0	-	Civ. Def. Director, Lake Co.
Lower Flathead and Lower Clark Fork	Flathead near Polson	-	-	Civ. Def. Director, Lake Co. Flood Coordinator, Sanders Co.
	Clark Fk. near Plains	17.3	110,000	
Pend Oreille Lake and River	Pend Oreille Lake at Hope	62.5	-	Civ. Def. Director, Bonner Co.
	Pend Oreille at Newport	47.3	106,000	Engineer, Pend Oreille Co.
Spokane and Coeur d'Alene	Coeur d'Alene at Cataldo	-	-	Engineer, Shoshone Co.
	Coeur d'Alene Lake at Coeur d'Alene	34.0	-	Civ. Def. Director, Kootenai Co.
	Spokane at Spokane	28.5	42,600	Engineer, Spokane Co.
St. Joe	St. Joe at St. Maries	35.5	-	Flood Coordinator, Benewah Co.

Accomplishments

Kootenai River Basin

Levees protecting Kootenai Flats are effective up to a river stage of 35 feet at Bonners Ferry. The completion of Libby Dam will substantially eliminate flooding at Troy, Bonners Ferry, and Kootenai Flats. A 100-year flood will be controlled to a 27-foot stage at Bonners Ferry, and most smaller floods will be held to 23.5. With this control, the existing Kootenai Flats levee system will provide a high degree of protection to the 32,290 acres of valley land. Libby Dam will reduce average annual damages in the subregion by \$910,000, and will assist in the control of the lower Columbia River.





FIGURE 5

Clark Fork-Pend Oreille Basin

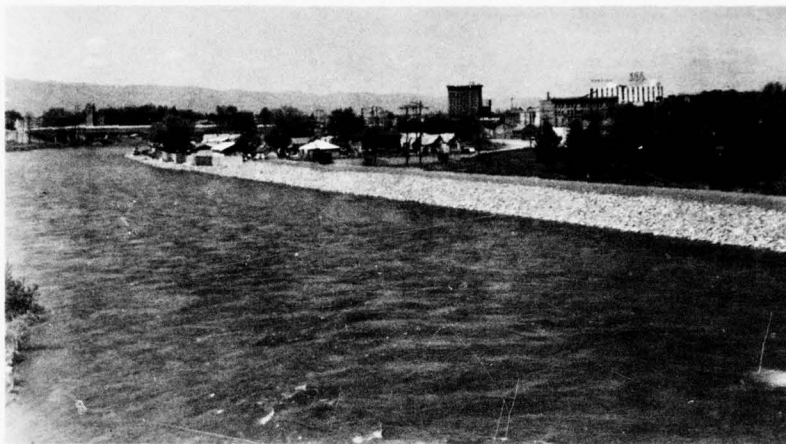
Storage The only significant flood control storage effective in the Clark Fork-Pend Oreille Basin is on the Flathead at Hungry Horse Dam (South Fork) and Kerr Dam (main stem). Most of the effectiveness is at Hungry Horse with Kerr Dam permitting somewhat more efficient use of the natural storage in Flathead Lake (table 14.) Flathead Lake, Noxon Rapids, and Lake Pend Oreille are effective in control of the lower Columbia River (see table 82).

Table 14 - Regulation by Hungry Horse, Subregion 1

Date	Location	Unregulated	Regulated	Damages Prevented
1964	Above Flathead Lake	245,000 cfs	176,000 cfs	\$10,000,000
	Flathead Lake	97.1 ft.	94.4 ft.	731,100
	Clark Fork at Plains	137,500 cfs	121,000 cfs	145,800
	Pend Oreille Lake	68.0 ft.	64.3 ft.	497,800
	Pend Oreille River	135,500 cfs	123,000 cfs	434,800
				\$11,809,500
1967	Above Flathead Lake	87,400 cfs	55,600 cfs	\$ 3,618,000
	Flathead Lake	94.5	93.0 ft.	21,000
	Lower Flathead	63,600 cfs	45,400 cfs	17,900
	Pend Oreille Lake	65.1 ft.	62.5 ft.	92,400
	Pend Oreille River	124,000 cfs	106,400 cfs	341,800
				\$ 4,091,100

Levees and Channels Present protection provided by the levees at Missoula ranges from control of 21-year frequency floods to nearly complete protection. Orchard Homes, the suburban tract downstream, is not protected from flooding, but damages are decreased through reduction of velocities. The two levees across the river from Plains offer a moderate degree of protection to about 1,000 acres, including several hundred acres of cropland and the county fairgrounds. The levees along the Pend Oreille River near Cusick protect 9,800 acres against floods up to a 67-year frequency. Other levees along the Pend Oreille give a lesser degree of protection. The interior levees along Kalispell Creek protect a total of 1,140 acres against floods of 4 to 8-year frequency. The levee at St. Regis protects the town against moderate flooding of the St. Regis River.

The levees along the Flathead River in the vicinity of Kalispell give differing degrees of protection: 240 acres have 100-year protection; 700 acres have 30- to 35-year protection; and 640 acres have from 4 to 25 years. The levee on Lightning Creek provides 200-year frequency flood protection to the town of Clark Fork and greatly reduces the possibility of the creek making a channel change which would take it through the town.



Levee at Missoula, Montana, 1958. (USCE)

The improved channel through Deer Lodge has a capacity of 750 cfs, which controls a 10-year frequency flood on Cottonwood Creek.

Spokane River Basin

Storage There is no flood control storage in the Spokane Basin.

Levees Along the lower Coeur d'Alene River, the railroad embankment on the left bank and the levee on the right bank near the mouth protect a total of 1,420 acres. The right bank levee at Dudley provides a high degree of protection for 800 acres of farmland; the top of the levee is about 7 feet above a 2-year frequency stage. The levee at the city of Coeur d'Alene provides practically complete protection from high water on Coeur d'Alene Lake even allowing for wave action. The levees on Pine Creek provide 15-year frequency protection to Pinehurst and 10-year frequency protection to the community of Pine Creek. The levee on the St. Joe at St. Maries provides about 200-year frequency protection to the town. However, adjoining diking district levees, which protect a total of 3,900 acres of crop and pastureland, are about 9 feet lower. The 5-year frequency flood of 1956 approached to within 1 to 2 feet of the top of these levees and caused failure of one.

Flood Control Channels The capacity of the Placer Creek channel through Wallace, Idaho, is about 1,000 cfs, which is exceeded about every 3 years. Floods causing serious damage have about a 15-year frequency.

The new channel of the South Fork Coeur d'Alene River at Wallace will be designed for a flow of 50-year frequency but is expected to prevent serious damages from floods up to a 100-year frequency. This work, however, will not improve the carrying capacity of Placer Creek.

The 4.5 mile improved channel of Hangman Creek upstream from the Washington-Idaho State line has a capacity of 1,000 cfs, and provides 4-year frequency protection to the town of Tensed and 1,300 acres of farmlands.

Tributary Watershed Areas

Five comprehensive watershed projects have been constructed or are under construction. Within these project areas, average annual damages are reduced \$36,000 on 4,000 acres of agricultural land. Land treatment measures in other areas reduce erosion and sedimentation and assist in reduction of flood flows.

Remaining Flood Problems

Kootenai River Basin

Libby Dam is designed to control a 100-year frequency flood to zero damage stage of 27 feet at Bonners Ferry, but the existing levee system must be maintained and protected against erosion.

Flooding of tributary streams has been reported at Libby, Montana, and may occur elsewhere in the basin. Generally, this problem is brought about by the accumulation of debris and vegetation.

Clark Fork-Pend Oreille and Spokane Basins

Records of flood damages and inventories of flood areas have been carried on for many years by various government agencies. The acute problem areas have been identified and are presented on table 15.

Tributary Flood Problems

In the tributary areas (drainage areas 400 square miles or less) more than 102,000 acres of cropland, 48,000 acres of forest land, and 30,000 acres of range and pastureland are subject to flooding. There is serious streambank erosion on 0.8 percent (325) miles of the 41,830 miles of channels and moderate streambank erosion on 7.2 percent (3,042 miles). Appendix VIII contains more information on these areas.

Streambank Erosion

The character of the soils exposed to stream erosion varies from the glaciated terraces and fans of the Kootenai, upper Flathead, and Blackfoot basins to the bottom lands and glacial till of the lower Flathead, Bitterroot, and Clark Fork basins, and the loessal hill land of the Spokane Basin.

An estimated 385 miles of streambank are subject to serious erosion, which, at an estimated average annual lateral retreat of 0.6 feet, causes an average annual land loss of 28 acres. Eroded material which is not deposited on the flood plain is carried downstream into the Columbia River. Average annual damages, including land loss and sedimentation costs, are an estimated \$334,000.

Table 15 - Remaining Flood Problems, Subregion 1

Major Drainage	Location	Frequency or Flow at which Damage Occurs	Frequency or Flow at which Major Damage Occurs	Average Annual Damage in Dollars	Damage Occurs to	Comments
Clark Fork	Upstream from Blackfoot River	3-year	7-year	\$ 3,600	Transportation facilities	Damages mainly occur at Bonner, Drummond, and Deer Lodge.
Clark Fork	Missoula	32,500 cfs (21-year)	42,500 cfs (100-year)	16,400	Residences, industries, transportation facilities	Minor damage only up to 20-yr. freq.
Clark Fork	Below Bitterroot River	5-year	20-year	3,000	13,000 acres irrigated cropland	
Clark Fork	Plains	12-year	-	6,000	1/2 agriculture 1/4 to City of Plains 1/4 to transportation facilities	Only 20% of the flood-susceptible area is inundated by a 25-year frequency flood.
Pend Oreille	Pend Oreille Lake	12-year	18-year	67,000	20,350 acres	Damage occurs at (1) The Clark Fork Delta; (2) The Pack River Delta; (3) Oden Bay; (4) Sandpoint; and (5) Morton.
Pend Oreille	Downstream, from Albeni Falls Dam		20-year	103,000	Agriculture near Cusick, 2,200 acres on Calispell 4,000 acres	Damages occur over a wide area.
Clark Fork	Cottonwood Creek	10-year	-	3,900	Urban and commercial	Damages occur mostly at Deer Lodge on 32 acres.
Clark Fork	Blackfoot River		-	2,900	Agriculture, urban, and transportation.	Most of the damage occurs upstream and at Lincoln, Montana
Clark Fork	Bitterroot River	9,450 cfs	-	37,000	Agriculture and woodland 19,000 acres	River flows in many channels resulting in serious control problems.
Clark Fork	St. Regis River	8-year	15-year	10,000	Transportation facilities and utilities 800 acres	Damages occur at St. Regis.
Clark Fork	Flathead River (Between Columbia Falls and Flathead Lake)	3-1/2 year	60-year	211,300	30,000 acres land, crops, and farm buildings	Frequent flood common and caused by multiple old river channels.
	Flathead Lake	35-year	1,000+ year	3,600	1,400 acres	300-year frequency would inundate Hwy. 104 and Perma downstream from Kerr Dam.
	Flathead River (Swan River)	20-year	-	16,300	15,000 acres agricultural and residential.	Damage occurs primarily along the east shore of Swan Lake.
Several tributaries of the Flathead River caused considerable damages in the 1964 flood. Principal problems were on the Middle Fork, Bear Creek, and the Whitefish Rivers.						
Spokane River	Coeur d'Alene River		60-year	40,000	17,800 acres	Levees protect most of the towns along the river.
Spokane River	Coeur d'Alene River	6-year	25-year	89,000	Summer homes and resorts and agricultural damage.	Wind and wave action are the critical factors determining the extent of damage.
Spokane River	Placer Creek	15-year	-	105,000	39-acre residential	Occur at Wallace.
Spokane River	Pine Creek	10-15-year	-	38,000	Buildings, streets, and utilities.	Most damages occur at Pinehurst.
Spokane River	St. Joe River	-	-	12,000	-	-
Spokane River	Spokane River	14-year	50-year	30,000	Residential, commercial and industrial property.	-
Spokane River	Hangman Creek	-	-	257,000	All types of land and property.	Damages occur between Waverly and Spokane. Also in the towns of Tensed and Tekos.
	Little Spokane R.	Not known	-	Not known	Suburban development.	Recent developments in the flood plain are creating a problem.
Tributary areas				\$1,584,000	Agriculture, small urban areas.	Includes land damages.

PROJECTIONS AND NEEDS

General Economic Trends

Although the population of Subregion 1 is expected to grow at a somewhat lesser rate than the region as a whole, by 2020 the 1965 population of 595,100 is forecast to increase to 1,140,400. Most of this growth will be in the larger cities, such as Spokane, Missoula, Coeur d'Alene, and Kalispell, where the major industries are located. Smaller communities giving evidence of growth are St. Maries and Columbia Falls. The rural population is expected to decline as a result of declining employment in agriculture and food processing, although agricultural production and value added are expected to increase. The greatest employment growth in manufacturing is anticipated in paper, chemicals, and primary metals.

Land Use Trends in Flood Plain

Use of the flood plain probably will continue as at present with some expansion of urban facilities at communities such as St. Maries and Smelterville where development onto higher ground is not practicable. Expansion at Spokane, Coeur d'Alene, Deer Lodge, and Columbia Falls probably will be on high ground, but developments at Missoula and Kalispell are tending to occupy the flood plain as well as available high ground. Agriculture on the flood plain is expected to continue producing primarily beef, feed crops, and potatoes. As shown in table 16, average annual damages in the major flood problem areas are projected to increase from just over \$1 million at present to nearly \$5 million by 2020.

Discussion of Flood Control Needs

Some general observations may be made about the nature of flood control needs in the subregion, particularly the Clark Fork-Pend Oreille and Spokane River Basins. The main stream flood problems of the Kootenai basin will be almost entirely eliminated by construction of Libby Dam.

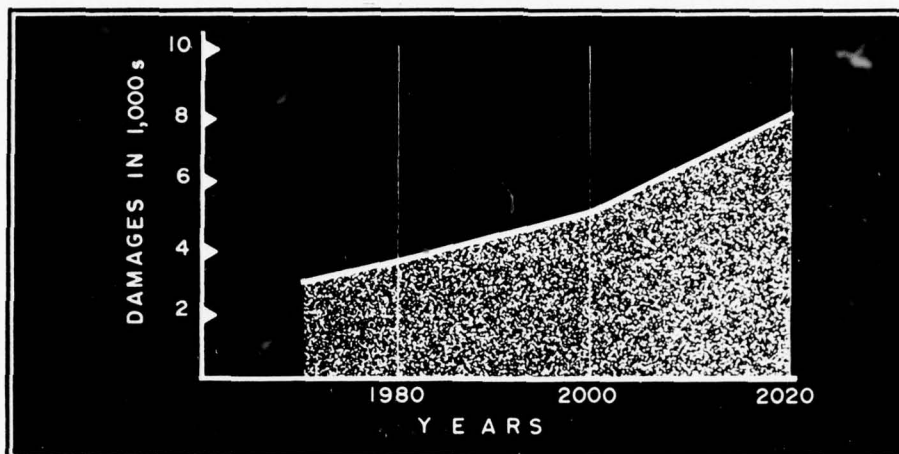


Figure 6. Projected Average Annual Flood Damages, Subregion 1.

Table 16 - Present and Future Average Annual Damages,
Subregion 1

Stream Basin	Damages in \$1,000, 1967 Price Levels					
	Present		Total	1980	2000	2020
	Rural	Urban 1/				
Clark Fork-Pend Oreille	206	49	255	329	467	716
Bitterroot	22	15	37	47	68	108
St. Regis	2	8	10	14	23	42
Flathead	111	121	232	352	642	1,237
Spokane	20	189	209	356	738	1,641
Placer Creek at Wallace	-	105	105	149	267	517
Hangman Creek	170	87	257	325	448	680
Streambank Erosion, All Basins	334	-	334	430	500	670
Minor Tributaries	1,466	118	1,584	1,853	2,122	2,408
Total Subregion	2,331	692	3,023	3,835	5,275	8,019

1/ Includes transportation, commercial, industrial, and residential.

Clark Fork-Pend Oreille Basin

Along the main river, three major problem areas are apparent. Although much of Missoula now is protected by levees, development in several areas not protected could proceed at a faster rate than indicated by table 16. Pend Oreille Lake has a growing resort and summer home flood problem which is tied to

control of the lake elevation. Although the construction of Albeni Falls Dam and the improvement of the outlet channel between the lake and the dam have made it possible to achieve a degree of control of the lake surface elevation, control is lost at about an 18-year frequency flood and the growing development adjacent to the lake is creating a situation in which significant flood damages will occur. Downstream, there are large agricultural losses along the Pend Oreille River which will demand attention as farm production increases in value.

Several tributaries have expanding flood problems. Deer Lodge, on Cottonwood Creek, has a population of 4,681 (1960) and is growing rapidly. Flooding from the creek is expected to become an increasing problem. The wide Flathead River valley has perhaps the greatest requirement for flood control in the subregion. The city of Kalispell is building out onto the flood plain and valley lands have a large agricultural potential if the river can be confined to its channel. Recreational development of the Swan Lake shoreline, not far from Kalispell, is expected to continue steadily. The increasing value of lake frontage will emphasize the need for control of the lake level. Flooding of agricultural land on Calispell Creek is related to flow on the Pend Oreille and operation of Box Canyon Dam for power. Study of possible solutions is now underway locally.

Spokane River Basin

Neither Kellogg nor Smelterville has room for expansion except on the flood plain. More damages to the increasing number of resorts and summer homes are expected on Coeur d'Alene Lake unless lake levels can be controlled. Wallace, Idaho, is subject to overflow of Placer Creek. The average annual damages of \$105,000 indicate that preventive measures are needed, and the Corps of Engineers has completed a study recommending channel improvements, but the recommended improvements have not been authorized for construction at this time. Even with a slow rate of growth, damages at Pinehurst will be great enough to warrant some future action to control flooding of Pine Creek.

Flood control needs on the St. Joe River are not great at present but could grow significantly in the future. Expansion of the town of St. Maries can only take place outside the existing well-protected urban area.

Despite its passage through a large city, the Spokane River causes relatively little flood damage in Spokane. The pressure of the large adjacent population, however, may cause developments which will create additional hazards in this area and upstream



10. & 11. *Flooded: Lands with high potential use in the Kalispell, Montana area during June 1964 flood. (USCE)*



in the Spokane Valley. Flooding of the Little Spokane River in the suburbs north of Spokane may be of more importance in the future because of the trend towards residential development in the flood plain. Hangman Creek now causes large agricultural and urban damages which will slowly increase in the future. With Tekoa, Washington, and Tensed, Idaho, declining in population, most of the future increase will be in urban areas in the vicinity of Spokane.

Streambank Erosion

The annual loss of land due to streambank erosion is not expected to change except as influenced by corrective measures. The value of land loss and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being primarily based on removal costs, will remain constant. Future annual damages from this source are estimated to amount to \$430,000 in 1980, \$500,000 in 2000, and \$670,000 in 2020.

MEASURES REQUIRED TO SATISFY NEEDS

Measures to satisfy flood control needs include storage, channel and levee works, watershed improvements, and nonstructural measures such as improved land management practices and zoning. Flood plain zoning can be particularly important in this subregion because alternative large-scale structural measures do not appear warranted in many problem areas, even within the projected 50-year period of this study.

Storage

Storage Requirements

The approximate volumes of water in floods passing several given locations over and above bankfull flows are shown in table 17. Existing regulation has been considered, but the quantities are based on data from various sources and are not exact. They serve to indicate in a general way the problem of storage as related to flood control at a given area. The quantities shown for any point include those for points upstream, thus any storage developed for the Clark Fork at Missoula, the Blackfoot, Bitterroot, or Flathead Rivers would affect the Clark Fork at Plains and the Pend Oreille River.

Table 17 - Flood Volumes in Excess of Bank Full Flows,
Subregion 1

Location	25-Year	100-Year	200-Year (ac.-ft.)	500-Year
Clark Fork, Missoula	130,000	340,000	460,000	680,000
Clark Fork, Plains	29,000	300,000	540,000	1,140,000
Pend Oreille River, Newport	290,000	1,700,000	2,500,000	3,800,000
Blackfoot River	120,000	270,000	370,000	540,000
Bitterroot River	120,000	200,000	250,000	290,000
Flathead River, Columbia Falls	120,000	280,000	430,000	620,000
Flathead Lake	180,000	420,000	670,000	1,100,000
Stillwater River, Columbia Falls	-	160,000	-	-
Coeur d'Alene River	50,000	160,000	260,000	450,000
St. Joe River	110,000	400,000	580,000	1,130,000
Spokane River	8,000	100,000	230,000	390,000
Hangman Creek	15,000	35,000	50,000	70,000

Potential Reservoir Sites

The potential reservoir sites discussed herein are based on previous studies by the Corps of Engineers (17) and the Bureau of Reclamation (30). Only sites which would have a potential effect on control of flooding within Subregion 1 are included. Other sites such as Long Meadows and Meadow Creek in the Kootenai Basin and Paradise on the Clark Fork have been studied in developing storage plans for control of the Columbia River, but are no longer considered feasible in view of the control afforded by existing and under-construction projects. The remaining pertinent projects are shown on figure 5, listed in table 18, and discussed in the following paragraphs.

The Blackfoot River Basin contains a number of potential storage sites as shown on table 18 with no serious disadvantages. Ninemile Prairie is the only site in the basin that has been studied in detail. It has one of the lowest average storage costs and the capability of controlling flooding throughout practically the entire length of the Clark Fork. The Blackfoot River has been designated for inclusion in the National Wild and Scenic River system. (3)

The Flathead River has several sites where large storage projects could be developed, but the Middle Fork and main river (North Fork) above Columbia Falls are under consideration for inclusion in the wild and scenic river system. Of the potential projects above Columbia Falls, Glacier View, on the main river, would inundate a large area of big-game winter range in Glacier

National Park. Smoky Range, a downstream alternative with the same volume of storage, would inundate approximately 1,600 acres less bottom land than Glacier View. The average cost of storage at either site would be relatively low. The Spruce Park site on the Middle Fork Flathead is on another possible unit of the wild and scenic river system. A project has been investigated that would provide a large storage volume but the cost would be relatively high. A potential site on the Stillwater has not been investigated in sufficient detail to present any reliable data.

Table 18 - Potential Storage Sites for Control of Floods, Subregion 1

Stream	Site	River Mile	Reservoir Length (Miles)	Usable Storage (AF)	Average Cost of Storage (\$/AF)
CLARK FORK - PEND OREILLE BASIN					
Blackfoot	Lincoln Canyon	94	3	212,000	-
"	Terrill	52.4	22	408,000	-
"	Upper Ovando	51.7	8	138,000	-
"	Ovando	47	13	154,000	-
"	Ninemile Prairie	22	14	885,000	82
N.F. Blackfoot	Heinze	24	6	83,000	-
Clearwater	Myrick	10	15	131,000	-
Flathead	Glacier View	177	21	1,510,000	84
"	Smoky Range	166	26	1,510,000	84
"	Flathead Lake Outlet Improvement	76.5	-	690,000	18
"	Sloan Bridge	44.7	27.8 1/	400,000	260
"	High Buffalo Rapids	36.5	36 1/	668,000	224
"	Knowles	2.7	70 1/	3,084,000	140
M.F. Flathead	Spruce Park	50	15	600,000	298
Stillwater	Stillwater	28.9	9	150,000	-
Thompson River	Thompson	8	12	160,000	-
SPOKANE RIVER BASIN					
Coeur d'Alene	Leland Glenn	56.1	22	370,000	194
"	Enaville	38.0	27	700,000	174
"	Springston	5.2	44	2,595,000	65
N.F. Coeur d'Alene	Bumblebee	3.0	-	40,000	-
Hangman Creek	Tensed	69.0	-	-	-
Tributary Areas	1900 ponds & reservoirs			18,200	

1/ Reservoir extends to Kerr Dam.

One of the more effective and lower cost possibilities for developing flood control storage on the Flathead would result from increasing the capacity of the Flathead Lake outlet channel between the lake and Kerr Dam. At this time, the channel restricts the flow from the lake and much of the storage in the lake is filled during the early phase of the spring runout before flood conditions develop downstream. The improved channel would allow the lake to be held at minimum controlled elevation until the storage space is needed for flood control. It would improve the regulating capability of Kerr Dam and add 690,000 acre-feet of effective usable storage in the lake without changing either the minimum or maximum lake levels. Further, the increased channel capacity would allow control of the lake level during floods that exceed the capacity of the present channel. Investment cost is

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estimated at \$12,000,000 and annual operation and maintenance at \$26,000.

The three sites on the main Flathead River below Flathead Lake are alternatives for developing that reach of the river. The Knowles site near the mouth would require extensive railroad and highway relocations and would inundate 47,000 acres of cultivated and grazing land. Also, the reservoir would inundate a portion of the National Bison Range. High Buffalo Rapids, 34 miles upstream, has few of the problems associated with the Knowles site, and is generally more acceptable. The Sloan Bridge site, still farther upstream, would be a less efficient development, and the principal advantage would be less development cost. High Buffalo Rapids definitely should be considered for flood control storage. It may, however, be precluded by private construction of a low run-of-river power dam at the same location for which an application has been filed; see Appendix XV. The Thompson River site would provide some control of flooding of Pend Oreille Lake and River.

Spokane River Basin Of the three major storage sites on the Coeur d'Alene River, Springston would develop far in excess of known needs on the river and would inundate the entire lower valley including several towns. It also could increase seepage into several deep mines in the vicinity. The Enaville site is probably the most favorable in the basin. Leland Glenn site, farther



Outlet to Flathead Lake, 1958. (USCE)

upstream, would be a less efficient development and would have no advantage over Enaville except lower total cost. Neither the Bumblebee site on the North Fork nor the Tensed site on Hangman Creek about 5 miles upstream from Tensed, Idaho, has been studied in detail.

Levees

Clark Fork-Pend Oreille Basin

Clark Fork above Blackfoot River Damages are scattered along many miles of the Clark Fork above Blackfoot River but no definite information on potential levee sites is available. A large part of the flood damages is to transportation facilities for which levee protection usually is not practicable. Studies may be warranted in the vicinity of Bonner at the mouth of the Blackfoot.

Clark Fork at Missoula Approximately 2,300 feet of existing levees and 350 feet of flood wall would have to be raised, and 12,050 feet of new levee and 900 feet of new flood wall built to provide uniform protection through the city. Initial cost of this work would be in the order of \$1.4 million and annual cost for maintenance might be \$10,000. This does not include improving the protection of the suburban development downstream. A 4,500-foot levee extension at the latter location would cost in the order of \$275,000 with annual maintenance cost of \$1,500 and would prevent 80 percent of average annual damages.

Clark Fork below Bitterroot River No specific plan has been developed for the area along the Clark Fork immediately downstream from the Bitterroot River. On the assumption that levees would be required on one bank or the other for the entire 15-mile distance, a rough estimate of cost has been made. For 25-year frequency protection, construction cost would range from \$2.5 to \$3.0 million and annual maintenance over \$20,000.

Clark Fork at Plains In the absence of detailed studies, the assumption has been made that a levee 1.5 miles long would provide 100-year frequency protection to the town of Plains. Construction costs would be about \$600,000 and annual maintenance \$5,000 or more. For the agricultural area in the vicinity, an additional 3.5 miles of levee on the right bank and 2.0 miles on the left bank are assumed necessary for 25-year frequency protection. Construction costs would be approximately \$700,000 and annual maintenance \$5,000.

Pend Oreille Lake No estimate has been made for levees in the vicinity of Sandpoint as the majority of landowners are

strongly opposed to an embankment or floodwall which would obstruct their view and use of the lake. The flood-susceptible areas at Oden Bay and the Pack River Delta appear too narrow to make levees practicable.

Pend Oreille River Because of the existing high degree of protection (67-year frequency) provided by railroad embankment and levees near Cusick, no further improvements there have been considered. While data is limited for the rest of the Pend Oreille, improvement of protection to 25-year frequency at five areas where 10 miles of levees now provide something less than 25-year protection would prevent about one-third of all agricultural damages. Construction costs are estimated at about \$1,000,000 and annual maintenance over \$5,000.

Blackfoot River A levee plan for the Blackfoot River has not been developed. However, a potential 3,500-foot levee to prevent 200-year frequency floodwaters entering a former river channel and causing \$2,900 average annual damages at the town of Lincoln would cost an estimated \$55,000 with annual maintenance of \$500. Average annual damages would be reduced by \$2,500. The Blackfoot River has been designated for inclusion in the National Wild and Scenic River system. (3)

St. Regis River Levees have not been considered practicable in the exceptionally narrow St. Regis Valley except at the communities of Haugan, Saltese, and St. Regis. No specific studies have been made for Haugan. For Saltese, construction cost is estimated at \$130,000 and annual cost \$1,500. At St. Regis, raising the existing 4,800-foot levee is estimated to cost at least \$250,000 and have annual maintenance costs over \$1,000. The work would eliminate half the present flood damages.

Flathead River In the reach from Columbia Falls to Flathead Lake, protection against a recurrence of the 1964 flood would require levees at five locations with a total length of 25 miles. Total cost would approximate \$1.6 million and annual maintenance over \$10,000 to protect against a 100-year flood. Levee protection for the lands around Flathead Lake has not been studied. Downstream from Kerr Dam, only small tracts of land bordering the river are susceptible to damage.

Calispell Creek No improvements to levees on Calispell Creek have been considered, but an additional pumping plant with a capacity of 360 cfs to make existing levees more effective would supplement an existing 120 cfs plant in pumping confined Calispell Creek runoff into the Pend Oreille River. Construction cost is estimated at \$585,000 and annual operation and maintenance at \$6,000. Average annual damages amounting to \$31,000 would be prevented.

Spokane River Basin

Coeur d'Alene River Existing levees and railroad embankments along agricultural lands on the Coeur d'Alene River appear to provide an adequate degree of protection (60-year frequency) without major improvement. Unprotected agricultural lands in their present low state of development are not of sufficient value to support levee construction. At Smelterville and Kellogg on the South Fork only preliminary estimates of cost of improving existing embankments to increase protection from 60- to 100-year frequency have been made. For Smelterville construction costs would be at least \$300,000 and annual maintenance over \$2,000, and at Kellogg construction costs would exceed \$600,000 and annual maintenance \$3,000. Levee improvements at these two cities would prevent about half the existing flood damages in the Coeur d'Alene River Basin.

Coeur d'Alene Lake The only location on Coeur d'Alene Lake which appears to lend itself to levee protection is at Wolf Lodge Bay, where 380 acres could be given a high degree of protection by a low levee one-half mile long across the mouth of Wolf Lodge Valley. Construction costs are estimated at \$100,000 and annual maintenance over \$500. Information is not available on average annual flood damages at this specific location. Levees do not appear practicable for several other small areas and have not been considered for other, more developed locations as owners have been opposed to having their view and use of the lake obstructed.

Pine Creek Existing levees at the towns of Pinehurst and Pine Creek could be raised to increase protection from 10- to 15-year frequency at present to 100-year frequency. For Pinehurst, construction cost would be about \$650,000 and annual maintenance over \$3,500. For Pine Creek, construction cost would be about \$75,000 and annual maintenance \$500.

St. Joe River The existing levee at St. Maries, which provides 200-year frequency protection, is adequate without major improvement. However, the 16.9 miles of diking district levees enclosing agricultural lands would have to be raised to increase protection from 5- to 25-year frequency. Construction cost is roughly estimated at \$3,500,000 and annual maintenance \$20,000. Levees are not considered practicable for presently unprotected lands. The St. Joe River is included in the National Wild and Scenic River system. (3)

Spokane River As flooding is infrequent and the damageable area small along Spokane River in the vicinity of Spokane, any future levees probably would be confined to individual commercial

sites requiring individual protection. Proposed beautification of the waterfront will tend to inhibit commercial use.

Hangman Creek A levee in the reach from Tensed to Tekoa and related channel improvement 9.3 miles long, would provide 25-year frequency protection at a construction cost approximating \$900,000 and have annual maintenance cost exceeding \$5,000. At least 90 percent of average annual flood damages in that area would be prevented. This construction alone, however, could increase flooding downstream, especially in the vicinity of Tekoa. Investigation of levees at Tekoa, Spokane, and elsewhere is continuing along with a study of flood control by upstream storage.

Flood Control Channels

Clark Fork-Pend Oreille Basin

Cottonwood Creek at Deer Lodge A diversion channel to carry flows in excess of 750 cfs in Cottonwood Creek to nearby Johnson Creek with a diversion structure just downstream from Interstate 90 would cost an estimated \$110,000 and annual maintenance of \$900. Damages on Cottonwood Creek in Deer Lodge would be entirely prevented.

Swan River and Lake Dredging the outlet of Swan Lake and constructing a gated control to regulate lake levels would permit the 25-year frequency flood to be passed without the lake surface exceeding zero damage elevation 3,067.5. Control of the lake would include lowering the surface 5 feet below normal elevation 3,066 in advance of anticipated flooding. Construction costs are estimated to exceed \$900,000 and annual maintenance \$5,000. Approximately 98 percent of the flood damages would be prevented, and an equal benefit would be derived by making agricultural land suitable for residential use.

Spokane River Basin

Coeur d'Alene Lake Deepening the outlet of Coeur d'Alene Lake at the upper 6.5 miles of the Spokane River would allow better regulation of the lake surface by Post Falls Dam. With the channel so improved, and the dam spillway enlarged, releases of 40,000 cfs (zero damage flow of the Spokane River) could be made at lake elevation 2,130 during the early phases of a flood. At present, outflow of 40,000 cfs does not occur until the lake elevation approaches elevation 2,136 which is 2 feet above zero damage stage on the lake. A serious deterrent to further consideration of this improvement is the fact that the streambed of the Spokane River above Post Falls is perched 250 to 300 feet above

the water table. Any disturbance of the streambed might greatly increase the already significant seepage from the river and reduce the amount of water available for irrigation and power production farther downstream.

Placer Creek A 5,000-foot reinforced concrete channel which has a carrying capacity of 3,400 cfs would replace the existing inadequate channel in Wallace and virtually eliminate flooding by Placer Creek. Construction of such a channel has been recommended as a Federal project. The estimated construction cost and annual maintenance are \$2,200,000 and \$10,000, respectively.

Land Treatment and Minor Tributary Protection

A combination of improved management practices, land treatment measures and water control structures will be necessary to satisfy future watershed needs for flood prevention. The most effective cropland practices that are still needed in this sub-region are 605,500 acres of conservation cropping systems, 605,300 acres of crop residue use, and 118 miles of diversions and terraces.

Forest land treatment measures required to reduce sediment and overland flood flows are 180,500 acres of erosion control work and 5,275 miles of road and trail rehabilitation.

Rangeland practices required to reduce erosion and sediment and aid in reduction of flows include 139,100 acres seeded to grass, 79,200 acres of brush control and excessive grazing reduced on 60,400 acres.

Small flood control structures that will be needed include 1,900 farm ponds and small reservoirs with an aggregate storage of 18,200 acre-feet, 360 miles of levees, 1,500 miles of stream channel improvement, 35 miles of stream channel stabilization, 3,600 miles of streambank protection, and 900 miscellaneous other stream structures, all on lesser tributaries not previously presented as problem areas.

Comprehensive watershed treatment programs comprising land treatment and small flood control structures should be applied to 125 watersheds which have a total of 175,500 acres subject to flood damages. The works on these watersheds are included with the land treatment measures and small flood control structure cited above.

Additional information on the land treatment and small tributary measures, including a schedule of application, is included in Appendix VIII.

Streambank Erosion

Treatment of eroding streambanks is possible through either structural or vegetative means. The use of vegetative protective measures would be confined to smaller streams and headwaters. The average cost of vegetative protection is estimated at \$8,000 per mile. Structural protective measures would be predominantly rip-rap, having an estimated cost of \$40,000 per mile. An estimated 75 percent of seriously eroding streambank will require treatment prior to 2020 at a total cost of about \$4,200,000.

Flood Plain Zoning and Flood Proofing

There is an immediate need for flood plain zoning regulations for areas along the Clark Fork near Missoula and Orchard Homes, along the Flathead between Kalispell and Columbia Falls, along the Spokane River upstream from the city of Spokane to Lake Coeur d'Alene and on the Little Spokane River in the vicinity of Spokane. Areas with less pressing needs for such regulations exist along Clark Fork and Cottonwood Creek at Deer Lodge, along the Clark Fork in the vicinity of Plains, along St. Joe River upstream from St. Maries, and along Hangman Creek in the Spokane area. There are many other areas throughout the subregion where development in the flood plain could occur but is not indicated at this time.

Lakeshore easements around Pend Oreille Lake, obtained by the Federal government in connection with the construction of Albeni Falls Dam, require the ground floor of new buildings to be above elevation 2,067.5, which represents approximately a 25-year flood. These requirements should be reviewed to see if additional restrictions are desirable. A 100-year flood would raise the lake elevation to 2,070. Minimum ground floor elevations should be established for low-lying lands along the lower Coeur d'Alene River, around Coeur d'Alene Lake, within the city of Spokane, and within leveed lands in the vicinity of St. Maries. Other flood proofing measures should be applied at the small towns of Bonners, Milltown, and Drummond along the Upper Clark Fork and at the towns of Osburn, Kellogg, and Smelterville along the Coeur d'Alene.

It is estimated that prompt and effective zoning regulations and strict adherence to flood proofing practices on any necessary construction in the flood plains would prevent damages averaging \$84,000 in 1980, \$433,000 in 2000, and \$1,345,000 in 2020.

SUBREGION 2

UPPER COLUMBIA

GENERAL

Location and Extent

Subregion 2 encompasses 22,451 square miles in eastern Washington and contains the main Columbia River and all tributaries except the Spokane River from Canada to the Yakima River Basin on the right bank and to the Snake River Basin on the left. It is bounded on the west by Subregion 11, on the southwest by the Yakima River Basin, on the southeast by the Snake River Basin, on the east by the Spokane and Pend Oreille River Basins, and on the north by Canada.

Topography

Downstream from the Spokane River the Columbia River flows west, south, and southeast in a large semicircle, called the Big Bend, which divides the topography of the subregion into two distinct parts. The section north and west of the Big Bend is mountainous, with crests rising to over 10,000 feet in the north Cascades. South and east of the Big Bend lies the Columbia Plateau, a lava-formed table land sloping gently southward from 3,000 feet elevation near Spokane to about 400 feet at Pasco. The valley of the Columbia is narrow, generally a rock-walled gorge 300 to 2,000 feet below the surface of the adjoining plateau. In the wider portions of the valley, benches and terraces are found at various heights above the river. At no point is there an appreciable flood plain. Tributary streams also have narrow valleys and restricted flood plains.

Climate

The summers are dry and warm, and the winters moderately cold and wet. Average annual precipitation decreases from over 100 inches along the higher Cascade slopes to less than 7 inches on the Columbia Plateau. About 75 percent of all precipitation falls during the period October through March, most stations recording maximum monthly amounts in December. However, many stations record occasional heavy showers and thunderstorms during May and June. Most wintertime precipitation falls as snow, remaining on the ground at higher elevations after mid-November.

Average annual snowfall ranges from 300 inches on the highest slopes of the Cascades to less than 10 inches on the Columbia Plateau. Coldest temperatures occur when continental arctic air is pushed into the basin through the lower mountain passes to the north. Temperatures below 0°F. are not uncommon under these conditions. Summertime temperatures range from approximately 90°F. in the afternoons to nighttime lows of 50°F. Temperatures exceed 100°F. 1 or 2 days each year.

Economic Development

The population of this subregion in 1965 was 198,600. Three cities with populations greater than 10,000 are Wenatchee, 17,800; Pasco, 15,800; and Moses Lake, 10,159. Four other cities have populations greater than 2,500.

Two main railroad lines cross the subregion east to west and a third serves the southern tip near Pasco. Major east-west highways are U. S. 2, through Wenatchee, and Interstate 90, through Moses Lake. Major north-south highways are U. S. 97, through Wenatchee, and U. S. 395, through Colville. A commercial airline has regularly scheduled flights to Wenatchee, Pasco, and Ephrata, and charter service is available to other cities.

More than 20 percent of the work force are employed in agriculture and food processing. Principal crops include fruits in the Wenatchee, Chelan, and Okanogan Valleys and wheat on the dry-farmed portions of the Columbia Plateau. The Columbia Basin irrigation project allows diversified farming over a large portion of the latter area. Other important basic industries include production of lumber and primary metals.

Streams

Major streams and tributaries with drainage areas and flow characteristics are shown in table 19.

Columbia River Main Stem

The Columbia River enters the United States in the Northeast corner of Washington, flows generally south for 110 miles past the confluence of the Spokane, and then swings west, south, and southeast for 300 miles in the Big Bend which takes it to the mouths of the Yakima and Snake Rivers at the southern tip of the subregion. From the International Boundary to Priest Rapids Dam, the river is impounded in a series of reservoirs. From Priest

Rapids Dam to Lake Wallula, it is open river and drops 66 feet. Flows are low from October through March, increasing with snow-melt to a peak, generally in June.

Table 19 - Streamflow Characteristics, Subregion 2

Stream	Total Drainage Area, Sq. Mi.	Gage Location	Gage Drainage Area sq. mi.	Flow in cfs		
				Ave. ^{1/}	Max. ^{2/}	Min. ^{2/}
Columbia	96,800 ^{3/}	Priest Rapids Dam	96,000	114,100	692,600	4,120
Kettle	4,140 ^{4/}	Laurier	3,800	2,852	35,000	88
Colville	1,020	Kettle Falls	1,007	299	3,230	1
Sanpoil	979	Keller	890	NA	3,920	32
Okanogan	8,340 ^{4/}	Tonasket	7,280	2,894	40,900	126
Similkameen ^{5/}	3,591 ^{4/}	Nighthawk	3,550	2,286	38,700	120
Methow	1,794	Twisp	1,330	1,376	40,800	134
Chelan	924	Chelan	924	2,003	16,000	0
Entiat	419	Entiat	419	NA	5,380	29
Wenatchee	1,327	Peshastin	1,000	3,010	32,300	183
Moses Coulee	924	Palisades	844	NA	1,990	0
Crab Creek	4,864	Irby	1,042	96	8,370	2
Esquatzel Coulee		Connell	240	NA	5,560	0

^{1/} Regulated values for base period (1929-1958), 1970 conditions.

^{2/} Observed values for period of record.

^{3/} Includes upstream drainage in Canada and Subregion 1.

^{4/} Includes upstream drainage in Canada.

^{5/} Tributary of Okanogan.

Mountain Section Tributaries

The Kettle River rises in British Columbia, swings southerly for a short distance into and out of the United States and then returns to the United States where it flows nearly due south for 33 miles to Franklin D. Roosevelt Lake. In its upper reaches the river passes through deep narrow gorges, but farther downstream its valley floor widens to about 0.5 miles wide.

The Colville River is 53 miles in length and comparatively flat in its upper reaches, falling only 135 feet in the 37 miles above Kettle Falls. Its valley in this portion is 1 to 3 miles wide. Below Kettle Falls (river mile 5) the valley is steep and narrow to its confluence with the Columbia in Franklin D. Roosevelt Lake.

The Sanpoil River rises at a low divide separating it from the Kettle River basin and flows 62 miles south to Franklin D. Roosevelt Lake. Its average fall of 19 feet per mile is relatively uniform throughout its length. The valley floor of the Sanpoil rarely exceeds 1 mile in width.

The Okanogan River (Okanagan in Canada) rises in Canada, enters the United States near Oroville, Washington, and flows south to the Columbia near Brewster (river mile 534). It has a length of 82 miles in the United States and falls only 165 feet

in that distance. Near Oroville, a few miles below the Canadian border, it is joined by the Similkameen, which also originates in Canada. The Similkameen falls 280 feet in its 27-mile length in the United States and has a total average runoff which is four times that of the Okanogan at their confluence. Large flows on the Similkameen cause backwater and occasionally a reversal of flow on the Okanogan in the Oroville area. The Okanogan valley floor slopes upward away from the riverbanks forming a U-shaped valley.

The Methow River flows southeast 83 miles to the Columbia. Its valley is generally about a mile wide except for a narrow gorge in the lower reach. Average fall is 22 feet per mile.

The Chelan River is the outlet for the picturesque Lake Chelan. It flows 4 miles from the lake to the Columbia, falling 415 feet in that distance. Lake Chelan is 50 miles long, about 1 mile wide, and nearly 1,500 feet deep.

The Entiat River flows southeast 42 miles to the Columbia. The gradient is steep, averaging 50 feet per mile, and the valley is narrow.

The Wenatchee River flows southeast 54 miles from Lake Wenatchee to the Columbia River near the city of Wenatchee. Downstream from Leavenworth there are extensive areas of bottom lands.

Columbia Plateau Tributaries

The tributaries which flow into the Columbia River from the Columbia Plateau are different in character from those which rise in the mountain section. Moses Coulee is a former channel of the Columbia River cut 500 to 1,000 feet deep and 1 to 2 miles wide into basalt rock. It runs southwest and joins the Columbia about 5-1/2 miles below Rock Island Dam. Flow is intermittent, occurring only during snowmelt runoff. The only significant tributary is Douglas Creek, which runs into Moses Coulee at mile 17 and is responsible for most of its flow.

Crab Creek flows 175 miles southwest through Moses Lake to the Columbia River. Upstream from Moses Lake, flow is intermittent, the creek running underground during the summer in the vicinity of Odessa. An important tributary is Wilson Creek at river mile 97, downstream from Odessa.

Esquatzel Coulee runs southwest through Connell to join the Columbia River in the vicinity of Pasco. The flood plain is

only a few hundred feet in width. The streambed is dry throughout the late spring and summer months.

Flood Characteristics

Flooding is generally caused by the rapid melting of the snowpack in the spring. On the Columbia River and the tributaries of the mountain section flood peaks usually occur in late May or early June; a month earlier on the Colville. Because of its lower elevation, flooding on the Columbia Plateau usually occurs from January through March.

Intense rainstorms may occur in the winter, summer, or spring. When they occur in winter on frozen ground or accompanied by snowmelt, severe flooding may ensue.

HISTORY OF FLOODING

Major floods are listed in table 20. Discharges shown are those actually measured at the time of the flood. The damages are those which would occur if the discharge occurred with present day development and price levels. In some cases the discharge would have been reduced by subsequent upstream regulation.

On the Columbia River, peak flows generally are contained within banks, but banks were overtopped significantly in the floods of 1894 and 1948. In 1948, 300 acres were inundated and numerous residents were driven from their homes in the Richland area. (18) Levee protection at Richland has since been provided.

No significant flood damages have been reported on the Kettle, Sanpoil, or Chelan Rivers.

Floods on the Colville River occurred in 1938, 1948, 1952, 1956, and 1961. The maximum discharge of record occurred in April 1956, but the extent of flooding is not known. In April 1938, the second largest flood of record inundated 5,980 acres of agricultural land plus 1,620 acres of brushland. Crops, roads, bridges, and fences were damaged, and livestock was lost. (7)

Severe flooding occurred in the Okanogan Valley in 1894 and 1948. (18) During the latter flood the Okanogan River inundated portions of Oroville, Tonasket, Riverside, Malott, Omak, and Okanogan as well as 5,900 acres of rural land. Buildings and their contents, land, crops, roads, railroads, utilities, and irrigation and flood protection facilities were the principal items damaged.

During the 1948 flood in the Methow River Valley, agricultural lands and homes, business property, and utilities in the towns of Twisp, Winthrop, Carlton, Methow and Pateros, received major damage. (18) About 2,500 acres were inundated and bank erosion along the rivers resulted in a loss of 200 acres of orchard and farmland. The highway bridge and county road at Twisp were destroyed. Flood susceptible facilities in Pateros have since been moved to high ground in connection with the Wells Dam Project.

Table 20 - Major Floods, Subregion 2

<u>Stream</u>	<u>Date</u>	<u>Discharge</u> c.f.s.	<u>Measured at</u>	<u>Damage under</u> <u>Present</u> <u>Conditions</u>
Columbia River, main stem	Jun 1894	740,000 <u>1/</u>	Below Priest Rapids Dam	Minor
	May 1948	692,600		Minor
	Jun 1956	553,900		Minor
Colville River	Apr 1956	3,230	Kettle Falls	<u>2/</u>
	Apr 1938	2,690		<u>2/</u>
	May 1948	2,240		\$ 65,000
Okanogan River	Jun 1894	47,000	Below Tonasket	8,260,000
	May 1948	40,900		2,810,000
	Jun 1950	29,600		950,000
Methow River	May 1948	40,800	Twisp	2,400,000
	May 1942	21,300		<u>2/</u>
	Jun 1950	19,800		<u>2/</u>
Entiat River	May 1948	10,800 <u>1/</u>	Near mouth	650,000
	Jun 1916	5,380		<u>2/</u>
	Jun 1955	4,960		<u>2/</u>
Wenatchee River	May 1948	32,300	Near Peshastin Creek	2,043,000
	May 1956	24,200		<u>2/</u>
	Jun 1955	23,400		<u>2/</u>
Moses Coulee	Jun 1948	3,680	Near Palisades	1,650,000
	Feb 1957	2,600		<u>2/</u>
	Mar 1951	1,990		<u>2/</u>
Crab Creek	Feb 1957	8,370	Irby (below Odessa)	2,210,000
	Feb 1963	7,750		1,610,000
	Jan 1959	5,550		500,000
Esquatzel Coulee	Feb 1956	5,560	Connell	427,000

1/ Estimated

2/ Not available.

During the 1948 flood, the community of Ardenvoir was partly inundated by the Entiat River. Roads and bridges were washed out, a Federal fish hatchery was severely damaged, and 2,100 acres of orchard and pastureland were inundated. Buildings, farmland, and crops were damaged. (18)

The Wenatchee River washed out about 1,100 feet of the main line of the Burlington Northern Railroad during the 1948 flood, interrupting railroad traffic for 5 days. A section of U. S. Highway 2 was under water, and 800 acres of land were inundated. (18)

Discharges from Canyons 1 and 2, west of the city of Wenatchee, flow through the city to the Columbia River. Major flooding occurred in 1902, 1923, 1934, 1948, and 1957. In May 1957, a storm centered over Canyon 2 caused rocks, silt, and debris to be deposited in orchards and damaged buildings. Water in city streets resulted in severe backups and health hazards.

Moses Coulee near Palisades has been flooded frequently by high flows from Douglas Creek. Fourteen damaging floods have occurred since 1911. The 1948 flood, one of the most severe, was the result of a series of intense rainstorms. It washed out 15 miles of branch railroad and interrupted traffic on the main line of the Burlington Northern Railroad for a day. Silt and sand up to 2 feet in depth were deposited over a large portion of the 1,000 acres of irrigated agricultural land inundated by the flood. Roads, bridges, crops, and irrigation facilities were damaged.

Crab Creek has flooded seven times in 50 years upstream of Moses Lake, with damages at the towns of Odessa and Wilson Creek and adjacent agricultural areas. During a flood in February 1957 portions of Odessa and Wilson Creek, and 8,500 acres of agricultural land were inundated. Railroads, highways, roads, bridges, buildings and contents, lands, crops, irrigation, and flood control facilities were damaged; traffic was interrupted; and refugee care was required.

The only major flood in Esquatzel Coulee for which data is available occurred in February 1956. Runoff at Connell during 2 days was estimated at 5,000 acre-feet. Damages occurred at Connell, where levee protection was provided in 1966. Elsewhere damages amounted to \$160,000 at Mesa and \$165,000 in the rural areas, chiefly to railroad and highway facilities. Damages at Pasco were negligible.

PRESENT STATUS

Existing Measures

Flood Control Storage

Grand Coulee Dam has 5,232,000 acre-feet of active storage primarily for hydroelectric power and irrigation. Flood control storage is provided on a forecast basis. As initially constructed and operating as a single unit, the project could provide only about 1 million acre-feet of effective flood control storage, and that storage would in most cases fill prior to the arrival of the flood crest. Modification of the outlets to make the reservoir more effective for flood control was authorized in 1950 (7) but was not carried out because full effectiveness of the storage was also dependent upon availability of additional storage upstream. Completion of Canadian storage and Libby Dam, under the Columbia River Treaty of January 1961, together with development of the third powerplant at Grand Coulee, will make all the active storage at the project fully usable for flood control.

Conconcully and Salmon Lake Dams on Salmon Creek, a tributary of the Okanogan River, have a combined active storage capacity of 23,500 acre-feet. Spring runoff is stored for subsequent irrigation.

Control structures at Moses Lake and the Potholes Reservoir provide considerable regulation of floods on lower Crab Creek.

There are 2,530 farm ponds and small reservoirs on tributary streams with a total capacity of nearly 20,000 acre-feet.

Levees

Table 21 lists levees on which information is available. With the exception of Esquatzel Coulee at Connell, levees have been constructed by local interests although some have been reconstructed in part by the Federal government.

Flood Control Channels

No major channel improvements for flood control have been undertaken. Minor channel improvements have been made by local interests near river mile 12 on the Colville River at the mouth of Stranger Creek; at Peshastin on Peshastin Creek, a tributary of the Wenatchee River; with the Palisades Irrigation District

in Moses Coulee; and at various locations on Crab and Wilson Creeks. In 1947 and 1952, the Corps of Engineers improved the channel of the Okanogan just downstream from Osoyoos Lake.

Table 21 - Levees, 1970, Subregion 2

Stream	Location	Description
Columbia	Richland	Levee 3.2 miles long protects Richland. Corps of Engineers, 1952.
Kettle	Various locations	Miscellaneous local levees.
Similkameen	Oroville	Levees about 1.1 mile long on left bank protect Oroville.
Okanogan	Riverside	Levees about 1.1 mile long on left bank and 1.6 mile long on right bank protect Riverside.
Okanogan	Omak	Levees about 4,000 feet long on both left and right bank protect Omak.
Okanogan	Okanogan	Three levees on right bank totaling about 1.6 mile protect Okanogan.
Okanogan	Various locations	Miscellaneous levees.
Methow	Upstream from Winthrop	Two levees totaling about 0.9 mile on right bank protect fish hatchery facilities.
Twisp	Town of Twisp	Levee about 700 feet long on right bank and 600 feet on left bank protect town of Twisp.
Methow	Downstream from Twisp	Levee about 2,000 feet long on right bank protects road and irrigation ditch.
Methow	Various locations	Miscellaneous levees.
Entiat	Upstream from Crum Canyon	Levee about 700 feet long.
Entiat	Near Roaring Creek	Levees about 2,000 feet long on left bank about 750 feet long on right bank protect fish hatchery.
Wenatchee	Cashmere	Levee about 3,500 feet long on right bank protects Cashmere.
Moses Coulee	Various locations	Miscellaneous levees.
Crab Creek	Odessa	Levee (floodwall) 1,270 feet long protects Odessa.
Wilson Creek	Town of Wilson Creek	Two levees totaling about 1.5 mile protect town of Wilson Creek.
Esquatzel	Connell	Levees totaling 1.8 miles protect Connell. Corps of Engineers, 1966.
Various locations on minor tributary streams		Four miles of levees, 201 miles of stream channel improvements, 2 miles of stream channel stabilization, 205 miles of stream-bank protection, and 426 miscellaneous other stream structures.

Land Treatment

The most effective cropland treatment measures in Subregion 2 include conservation cropping systems on 1,489,000 acres, crop residue use on 1,239,000 acres, stubble mulching on 639,000 acres, and 49 miles of diversions and terraces. Nearly 2.2 million acres have adequate combinations of practices. Forest land

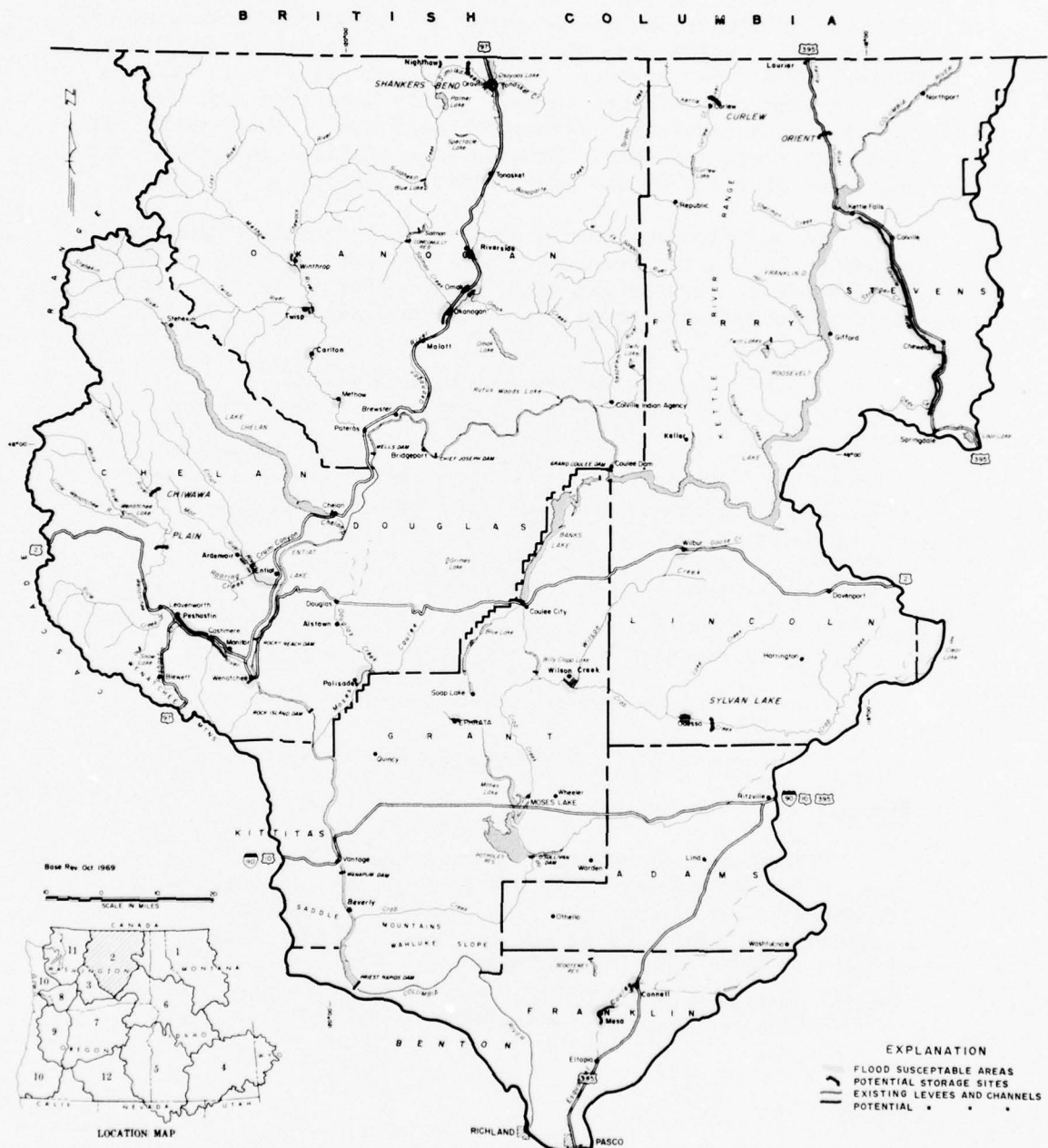


Terraces and contour farming increase water penetration, reduce erosion, and retard runoff; Wilber, Washington, 1968. (USCE)

treatment practices include seeding and gully stabilization on 35,000 acres and rehabilitation of nearly 2,200 miles of roads and trails. Rangeland practices include 117,000 acres of grass seeding, brush control on 42,000 acres, and excessive grazing control on 1.1 million acres. It is estimated that the soils of Subregion 2 have a water holding capacity of at least 5.887 million acre-feet. Additional information on watershed protection is included in Appendix VIII.

Flood Plain Regulation Program

No flood plain zoning ordinance has been enacted, nor are any studies underway. Flood plain planning at Richland related to the Yakima River is described under Subregion 3.



Flood Forecasting

Estimates of impending floodflows or stages and the expected time of occurrence are prepared by the River Forecasting unit at Portland, Oregon, and telephoned to the Spokane River District Office. The River District Office in turn calls civil defense and the sheriff's offices in each county concerned and advises the national news services. Through these channels local radio and TV stations are informed. Broadcasting stations in Spokane are contacted directly by the River District Office.

In addition to these channels of information, the Corps of Engineers in Seattle receives flood forecasts directly from the Portland River Forecasting unit for the benefit of flood engineers assigned to specific areas for flood emergencies (table 22).

Table 22 - Flood Emergency Areas, Subregion 2

Area	Gage	Zero Damage		Local Contact
		Stage ft.	Flow cfs	
Colville	Kettle Falls	6.5	560	Stevens Co. Engineer
Okanogan	Tonasket	88.5	17,000	Okanogan Co. Civil Defense Director
Methow	Twisp	6.4	15,700	Do.
Wenatchee	Peshastin	10.8	17,500	Chelan Co. Engineer
Douglas	Douglas	-	-	Douglas Co. Engineer
Crab	Moses Lake	-	-	Grant and Lincoln Co. Civil Defense Director

Accomplishments

Storage

Flood control storage at Grand Coulee Dam is a major element in control of the main Columbia River (see table 82). Conconully and Salmon Lake Dams provide nearly complete flood protection to 340 acres of hay and pastureland, 32 acres of orchards, roads, and farm buildings in Salmon Creek Valley. Storage in Moses Lake and Potholes Reservoir prevents any significant damage on Crab Creek downstream from O'Sullivan Dam.

Levees

Levees on the Columbia River at Richland provide 100-year frequency protection for 1,335 acres of urban area. On the Okanogan and Similkameen Rivers, levees at Oroville, Riverside, and Okanogan were constructed with a top elevation at or about

the 1948 flood level (70-year frequency). The levee on the Wenatchee River at Cashmere also was constructed to the 1948 flood level which in this case is about a 200-year frequency flow. The Wilson Creek levees were designed for different levels of protection. One section, from Seventh Street to the railroad bridge provides 100-year frequency protection. Levees at Connell protect 155 acres of urban land against 60-year frequency floods. Moderate protection is provided by the remaining levees listed in table 21.



Levee at town of Wilson Creek, Washington, January 1969. (USCE)

Flood Problems

There are no significant flood problems on the main Columbia, Kettle, Sanpoil or Chelan Rivers.

Colville River

Along the Colville River some flooding occurs about every other year and about 6,000 acres of agricultural land are subject to inundation from 75-year frequency floods in the 48-mile reach between Deer Creek and Kettle Falls. Flow is impeded by log jams and bridge piling. Of the 6,000 acres flooded, about 4,000 acres are damaged and the remaining 2,000 acres, which are of peat soil in the vicinity of Chewelah, are benefitted by flooding. Nearly all farm buildings and communities in the valley are above flood level. Average annual damages are estimated at \$14,000, nearly one-third to transportation facilities.



Areas along the Colville River during April 1956 flood. (USCE)



Okanogan River

Floods on the Okanogan River are largely the result of high flows from the Similkameen River. These floods cause widespread damage to low-lying cultivated fields and orchards. Field crops are destroyed and in some instances cannot be replanted because of the lateness of the season. Flooding and resultant rise of ground water level in low-lying orchards either kill the fruit trees or adversely affect the crop. The valley communities of Oroville, Tonasket, Riverside, Omak, and Okanogan are subject to damage by floods greater than 50-year frequency and some smaller communities more frequently.

Above Oroville, the lowlands adjacent to Osoyoos Lake are flooded frequently by high lake stages. Flooding around Osoyoos Lake is caused by restrictions at its outlet and by backwater from the Similkameen River. The lake outlet has been restricted in the past by deposition by silt and sand, possibly as a result of wave action. The outlet was enlarged by the Federal government in 1947 and 1952 but this was not a permanent improvement.

A natural obstruction exists in the Okanogan River channel about 1 mile below the outlet of Osoyoos Lake at the mouth of Tonasket Creek. This creek has a steep gradient, and although it is dry during most of the year, during floods it carries a large bedload of sand, gravel, and boulders, which it deposits in a debris cone in the Okanogan channel. In March 1939, this cone dammed the river and caused it to break through its right bank. The river channel at this point was dredged by the Federal government in 1947 and 1952. However, deposition has continued and the debris cone is approximately the same size as before. Tonasket Creek also causes damage by over-flowing its bank and depositing portions of its bedload on adjacent orchards.

Floods having a 10-year frequency inundate approximately 2,500 acres of agricultural land in the Okanogan Valley and damage rural homes and residential areas in Omak, Okanogan and Oroville. Portions of highways are inundated. Floods having a 100-year frequency cause damage to 4,200 acres of agricultural land. Residential and commercial buildings at Oroville, Tonasket, Riverside, Omak, and Okanogan are flooded, as well as many farm buildings throughout the valley. Considerable damage occurs to state and county highways, community water systems, sewage treatment plants, and the Burlington-Northern Railroad. Average annual flood damages within the United States amount to \$425,000 mostly to urban and transportation facilities.

Methow River

In the Methow River Valley, the developed portion of bottom lands subject to flooding comprises about 2,500 acres of towns and farms. High flows carry large debris loads and cause severe bank erosion. During high flows the towns of Twisp, Winthrop, Carlton, and Methow are flooded and bridges are damaged through the erosion of abutments. Average annual damages are estimated at \$30,000, mostly to agricultural lands.

Entiat River

In the Entiat River Valley the area subject to flooding consists of a total of 2,500 acres of separated irrigated farms near the river mouth. During floods the very steep gradient of this stream causes severe erosion. Average annual damages are estimated at \$32,000, about 25 percent of which are to urban and transportation facilities.

Wenatchee River

Flows of 20-year frequency on the Wenatchee River cause flooding of low-lying buildings in rural areas near Cashmere and Monitor. A repetition of the 200-year frequency 1948 flood would result in flooding of some buildings within Cashmere and throughout the valley, inundation of roads in several places, washouts of highways and railroad embankment and orchard lands, and closure of the Wenatchee city water plant. Failure of the levee at Cashmere could occur with widespread urban damages. Estimated average annual damage is \$150,000, mostly to transportation facilities.

The city of Wenatchee is not within the flood plain of the Wenatchee River; however, it is subject to damages from floods in Canyons 1 and 2 which flow through the city to the Columbia River. Significant damage has occurred about every 10 years. Approximately 2,900 acres of land are subject to inundation. Debris is deposited in agricultural and urban areas and city streets are flooded. Average annual damage amounts to \$400,000, mostly urban.

Moses Coulee

The flood susceptible area in Moses Coulee consists of 1,500 acres of improved agricultural land in and adjoining Palisades Irrigation District. Most damage occurs on 465 acres of the

irrigation district downstream from the mouth of Douglas Creek. Except in time of flood, there is no water flowing through the main coulee. Floods in the Moses Coulee Basin usually occur in the spring and are caused by snowmelt, particularly in the headwaters of Douglas Creek. The area in the main coulee is relatively flat compared to the gradient of Douglas Creek. The swiftly flowing floodwater of Douglas Creek spreads over the farmland and coulee bottom to depths of 1 to 3 feet, depositing large quantities of silt and sand. During severe floods, deposits have exceeded 2 feet in depth over a large portion of the irrigation district and roads and railroads have been destroyed. Damage from the 1948 flood was estimated at \$1,075,000 of which \$1 million was to the Burlington-Northern Railroad. Average annual damages have not been estimated.

Crab Creek

Along Crab Creek, most floods occur in December, January, and February, usually resulting from melting of the snowpack, sometimes augmented by rainfall on frozen ground. Zero damage flow of 3,000 cfs at Irby is exceeded about every 5 years. River-bank flooding may inundate up to 8,500 acres. A 50-year frequency flood (11,500 cfs) would inundate 95 percent of the business section and 70 percent of the residential section of Odessa. The flood problem in the town of Wilson Creek is complicated by saturation of the ground through subsurface flow from irrigated areas upstream. At the town of Wilbur on Goose Creek, a tributary of Wilson Creek, the restricted channel capacity has caused inundation of a large portion of the town during floods. Considerable damage is sustained at Ephrata from local runoff. Average annual damages on Crab Creek are estimated at \$318,000, chiefly to urban facilities in Odessa and Wilson Creek. Average annual damages on Dry Creek at Ephrata are estimated at \$83,000. No estimate has been made of average annual damages at Wilbur.

Esquatzel Coulee

The flood plain in Esquatzel Coulee averages only 350 feet in width. Most of the flood damages are to the main line of the Burlington-Northern Railroad, highways, and the town of Mesa. Approximately 2,400 acres are subject to inundation. Average annual damages amount to \$237,000.

Tributary Areas

The flooding in the tributary areas usually occurs in the spring from rapid snowmelt and/or warm rains. Less frequently,

warm winter storms cause rain and snowmelt floods complicated by frozen ground. Severe upland flooding does not always occur at the same time of the year or during the same years as on the major streams. Over 89,000 acres of cropland, and 22,000 acres of range and pastureland are subject to flooding. There is serious streambank erosion on 2.2 percent (397 miles) of the 17,997 miles of channels on the upstream areas (drainage areas under 400 square miles) and 14.1 percent (2,530 miles) have moderate streambank erosion. A total of 103 of the 113 upstream watersheds have combinations of problems, including 112,500 acres subject to flooding that require comprehensive treatment programs.

Streambank Erosion

The character of the terrain in Subregion 2 exposed to stream erosion consists of flood plains, sandy terraces, and steep sandy and stony canyon side slopes.

An estimated 419 miles of streambank are subject to serious erosion which, at an estimated average annual lateral retreat of 0.45 feet, cause an average annual land loss of 23 acres. Eroded material is carried downstream into the lower reaches of the Columbia River. Present average annual erosion damages, including land loss and sedimentation costs, are estimated at \$282,000.

PROJECTIONS AND NEEDS

General Economic Trends

The population of Subregion 2 is expected to grow at approximately the average rate of the region with the 1965 population of 198,600 forecast to increase to 431,300 by 2020. Much of this growth will be in the newly irrigated lands of the Columbia Basin, especially in the vicinity of Moses Lake where small communities like Othello and Warden are experiencing rapid expansion. Wenatchee and Chelan are expected to have substantial growth rates, the latter because of recreational attractions. Other centers of population where moderate expansion is likely are Omak, Okanogan, and Ephrata. The greatest increase in employment is expected to be in the paper, primary metals, chemical, and food processing industries.

Land Use Trends in the Flood Plain

Use of the flood plain probably will continue as at present with some expansion of urban facilities at Okanogan where

development onto higher ground is not practicable. High ground out of the flood plain is available at Omak. Part of any expansion at Wenatchee probably will be in areas subject to discharges from the hills to the west. However, most growth may be across the Columbia River where canyon discharges are less significant. Other centers of population like Chelan, Ephrata, Othello, and Warden are generally out of the flood plain. Use of flood plain lands for agriculture is expected to intensify.

Flood Damage Protections

Table 23 gives average annual damages for the major flood problem areas under present and future development. As described in the regional summary, future flood damages have been computed on the basis of projected total personal income for urban and transportation damages and projected crop yields for agricultural damages. However, for the Colville, Methow, and Entiat Rivers, and Crab Creek, which do not show active growth, the rate of increase of urban and transportation damages was reduced 50 percent.

Table 23 - Present and Future Average Annual Damages, Subregion 2

Stream Basin	Present (1967) Damages in \$1,000, 1967 Price Levels					
	Rural	Urban 1/	Total	1980	2000	2020
Colville	10	4	14	19	26	40
Okanogan	130	295	425	719	1,472	3,085
Methow	25	5	30	38	50	70
Entiat	24	8	32	43	57	86
Wenatchee	17	133	150	273	602	1,319
Canyons 1 & 2 at Wenatchee	15	385	400	747	1,692	3,766
Crab Creek	32	286	318	452	807	1,585
Dry Creek at Ephrata	-	83	83	157	360	805
Esquatzel Coulee	12	225	237	440	993	2,201
Streambank Erosion	282	-	282	400	560	850
Minor Tributaries	2,403	180	2,583	3,203	3,823	4,468
Subregion Totals	2,950	1,604	4,554	6,491	10,442	18,275

1/ Includes residential, commercial, industrial, and transportation.

The annual loss of land due to streambank erosion is not expected to change except as influenced by corrective measures. The value of land loss and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being primarily based on removal costs, will remain constant. Future average annual sedimentation damages are estimated to amount to \$400,000 in 1980, \$560,000 in 2000, and \$850,000 in 2020.

Summary of Flood Control Needs

The major damage areas, now and increasingly in the future, are on the Okanogan River, the city of Wenatchee, Crab Creek, Esquatzel Coulee, and the Wenatchee River. The Okanogan River flows through several cities (Omak, Okanogan, and Oroville), floods a number of smaller communities, lies adjacent to an important highway and railroad, and causes large agricultural damages annually. Damages from all causes will continue to increase in the future. Flooding of Lake Osoyoos may tend to occur in the future because of outlet restrictions including sedimentation at the mouth of Tonasket Creek. However, the Federal government has dredged the channel at this location in the past and would have authority to do so again should the need arise.

Flooding and debris problems caused by Canyons 1 and 2 in the city of Wenatchee will increase as urbanization of lands surrounding these watercourses continues. If uncorrected, this condition will eventually constitute the greatest source of damages in the subregion.

Although communities directly on Crab Creek now have static populations and agricultural damages are moderate, urban and transportation damages are so large that even small rates of increase will pose a substantial flood problem. In addition to damages at main stem communities like Odessa and Wilson Creek, which receive 75 percent of Crab Creek urban damages, there are problems on secondary tributaries at Wilbur and Ephrata.

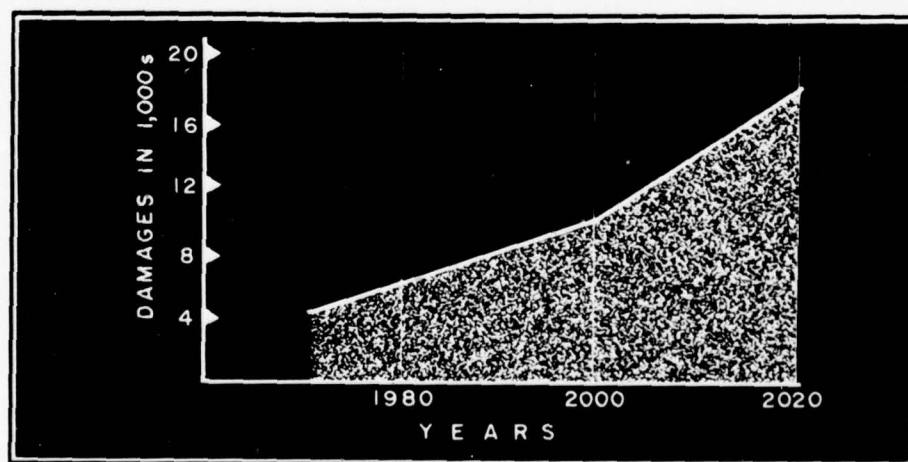


Figure 8. Projected Average Annual Flood Damages, Subregion 2.

Esquatzel Coulee flood damages are mostly to railroad facilities. The small community of Mesa has a static population, but the growing value of traffic to and from Pasco could result in large transportation damages in the future.

Damages on the Wenatchee River are considerably less than in the above areas; however, they are significant. The population of Cashmere, a town about 13 miles from Wenatchee, is growing and damages there are aggravated by flooding of Mission Creek, a tributary of the Wenatchee.

Less severe damages occur on the Entiat, Methow, and Colville Rivers. Most of the damages on the Entiat and Methow are agricultural which increase at a much lesser rate than urban damages. The Colville River has minor damages of which two-thirds are to agriculture and one-third to roads and bridges. As the Colville Valley has stabilized in population and productivity, the value of traffic is expected to increase at a relatively low rate in the future. Any plan for channel improvement on the Colville must consider the need for maintaining a high ground water table in the peat soils at Chewelah.

As previously noted, significant flood damages on the Columbia main stem, Kettle, Sanpoil, and Chelan Rivers have not been recorded. There is no current evidence of any future development in these valleys which would substantially change this condition.

Data from which to estimate average annual damages in the Moses Coulee area are not available. Although damages were determined following the 1948 flood, the data are not usable for computing average annual damages because the flood was caused by a cloudburst and neither the frequency nor the pattern of flooding was indicative of normal floods. The next largest flood of record, a snowmelt flood in 1957, had a peak flow of 2,600 cfs but damages by that flood were not determined. Neither channel improvement, levees, or storage in the canyon of Douglas Creek appears practicable. Detention dams above Douglas Creek to retain snowmelt runoff may be the only applicable measure.

Average annual damages in minor tributary areas are \$2,583,000 and are projected to increase to \$3.2 million, \$3.8 million, and \$4.5 million by 1980, 2000, and 2020, respectively. These damages are indicative of the need for land treatment measures and flood-control structures on the minor tributaries.

MEASURES TO SATISFY NEEDS

Measures to alleviate flood damages include channel and levee works, storage, watershed improvements, nonstructural measures such as zoning, and combinations thereof.

Levees

No detailed studies have been made for levee protection within the subregion. The following estimates are approximations of the costs necessary to provide 100-year frequency protection to several flood-susceptible communities. No estimates have been made for agricultural areas pending definition of specific areas subject to flooding. Except for the Okanogan Valley, agricultural damages are generally too small to justify extensive levee construction in the near future.

Okanogan River

Oroville A levee about 5.3 miles long would protect Oroville from flooding of Osoyoos Lake, the Okanogan River immediately downstream, and the Similkameen River. An area of 950 acres would be inclosed, including lands south of Oroville, but not including lands across the Okanogan River to the east.



Levee and flood walls at Odessa, Washington, 1959. (USCE)

Construction cost is estimated at \$3,000,000 and annual costs, excluding interest and amortization, at \$15,000.

Riverside A levee on the right bank to protect lands upstream and downstream as well as Riverside itself would be about 2 miles long and would enclose 400 acres. Construction cost is estimated at \$800,000 and annual maintenance at \$4,000.

Omak Omak could be protected by a levee about 2.1 miles long on the right bank and a levee about 1.1 miles long on the left bank. Construction cost is estimated at \$1,500,000 and annual maintenance at \$8,000.

Okanogan A levee 2.2 miles long on the right bank would protect 250 acres, including the central area of Okanogan and lands extending downstream. Construction cost is estimated at \$800,000 and annual maintenance at \$4,000.

Wenatchee River

Most of the agricultural production of the Wenatchee Valley is in the 24 river miles downstream from Leavenworth. This reach also includes the communities of Peshastin, Dryden, Cashmere, and Monitor, all subject to flooding. Approximately 12 miles of levee would provide protection against nearly all the flood damages in the reach. Construction cost is estimated at \$5,000,000 and annual maintenance at \$25,000. The Wenatchee River has been designated for inclusion in the National Wild and Scenic Rivers system.

Esquatzel Coulee

Mesa The estimated construction cost of 5 miles of levees to protect 810 acres, including Mesa, is \$1,600,000. Annual maintenance is estimated at \$8,000. The work would include necessary channel improvements.

Flood Control Channels

Colville River

Channel improvements appear to be the most practicable means of flood control in the Colville Valley. Most of the agricultural land in the valley lies in a bottom strip from 1 to 3 miles wide and about 60 miles long extending from the village of Grays to Kettle Falls. The stream gradient in this reach is very

flat, and flow is impeded by numerous sharp bends, overhanging brush, log jams, gravel bars, and other obstructive conditions. Because of the flat gradient, the capacity of the channel could be increased without danger of creating erosive velocities. Sufficient curvature could be retained to preserve esthetic interest and fish habitat. Special consideration would have to be given to retaining a high water table in a 15-mile reach near Chewelah to maintain the productivity of peat soils in that area.

Canyons 1 and 2, Wenatchee

A combination open and covered channel 10 to 14 feet in width, 4.5 miles long, would carry the 200-year frequency flood from Canyons 1 and 2 through Wenatchee to the Columbia River. Total construction cost is estimated at \$9,100,000 and annual costs for operation and maintenance at \$32,000. Details of this proposal are described in a 1969 survey report by the Corps of Engineers.

Crab Creek

Odessa A Corps of Engineers report in 1964 describes channel improvements to carry 50-year frequency flow (11,500 cfs) through Odessa. Work would consist of widening, riprapping, and providing concrete lining over a length of 6,200 feet through the town and constructing a diversion channel 3,435 feet long to bypass a restricted section of the natural channel downstream. Construction cost is estimated at \$1,100,000 and annual maintenance at \$6,000. Average annual flood damages of \$103,700 (estimated in 1964) would be prevented.

Wilson Creek Protection against 50-year frequency floods could be obtained by constructing a channel to carry Wilson Creek into Crab Creek along a better alignment, bordered by levees 10 to 15 feet high. The channel would carry maximum probable flows of Wilson Creek, and an existing railroad embankment would then protect against 50-year frequency flows of Crab Creek. This proposal is described in a 1958 Corps of Engineers report. Construction cost is estimated at \$885,000 and annual maintenance costs at \$5,000. Average annual flood damages of \$79,000 (estimated in 1958) would be prevented.

Ephrata A 1968 report by the Corps of Engineers describes improvements to Dry Creek which would permit passage of a 100-year frequency flood. Construction would include a rectangular concrete channel through the city and a trapezoidal unlined channel, bordered by levees, beyond to an existing watercourse.

Construction cost is estimated at \$1,700,000 and annual maintenance costs at \$8,500. Average annual flood damages of \$53,000 would be prevented.

O'Sullivan Dam Plans are being made to improve the Crab Creek channel below O'Sullivan Dam for better conveyance of expected future releases from the dam.

Storage

Potential Reservoir Sites

Several studies of water resource development in Subregion 2 have included examination of storage sites. These studies include the Corps of Engineers Columbia River reports of 1948 and 1958 (7, 8) and an unfavorable report by the Corps of Engineers in 1968 on Crab Creek (20). Table 24 is a listing of potential storage sites based on the above reports. The item "Average Cost of Storage" in the table was obtained by updating latest available construction costs (omitting power and irrigation facilities) and dividing by the amount of usable storage. This is only an approximation as the actual cost per acre-foot would vary with the height of dam and actual storage provided.

Table 24 - Potential Flood Control Storage Sites, Subregion 2

<u>Stream</u>	<u>Site</u>	<u>River Mile</u>	<u>Usable Storage (AF)</u>	<u>Average Cost of Storage (\$/AF)</u>
Kettle	Curlew	66.7	-	-
Kettle	Orient	23	280,000	-
Similkameen	Shankers Bend	7.3	1,620,000	42
Wenatchee	Plain	45.7	1,160,000	117
Chiwawa	Chiwawa	11.9	205,000	228
Crab Creek	Sylvan Lake	126	35,000	305
19,800 farm ponds and reservoirs			165,000	

Kettle River Detailed studies have not been made of either the Curlew or Orient site. Both would back water into Canada and would necessitate highway and railroad relocations.

Okanogan River The most favorable site in the Okanogan Basin is Shankers Bend on the Similkameen River near its mouth. The reservoir would extend 10 miles into Canada and would necessitate a minor railroad relocation. The storage capacity shown in table 24 is from House Document 531 (7) which describes a project for irrigation, power, and flood control. Approximately

500,000 acre-feet would be adequate to control floods of 100-year frequency on the Okanogan River.

Methow River At least six potential reservoir sites have been noted in the Methow Basin. No studies or cost estimates have been made, and construction would not be justified in the foreseeable future on the basis of flood control benefits alone.

Wenatchee River A reservoir at Plain with maximum pool at elevation 2,000 would raise the normal level of Wenatchee Lake 130 feet and would also inundate Fish Lake. Thirty-seven miles of state highway and 21 miles of other roads would require relocation. There are also a number of residences, camps, resorts, and summer cabins in the reservoir area. Flooding on the Wenatchee River would be practically eliminated and benefits from power production obtained.

The Chiwawa site is on the Chiwawa River, which enters the Wenatchee River 6 miles below Wenatchee Lake. Relocation and real estate problems would be minimal, and hydroelectric power could be obtained, but flood control benefits would be minor as compared with the Plains site.

Chelan County PUD has a license application to the Federal Power Commission for projects that would preclude development of the Plain and Chiwawa sites described here. However, their projects would provide a fair amount of seasonal storage which could be used for flood control. The Wenatchee and Chiwawa Rivers have been designated for inclusion in the National Wild and Scenic Rivers system. (3) Such inclusion would preclude either type of storage development.

Moses Coulee There are potential damsites in the Douglas Creek canyon which would control flooding in Moses Coulee. Relocation of the Burlington-Northern Railroad and probable loss of storage capacity by sedimentation would be necessary considerations. No detailed studies or cost estimates have been made.

Crab Creek A low dam at the outlet of Sylvan Lake, 4 miles upstream from Odessa would provide sufficient storage to control the 100-year frequency flood on Crab Creek.

Watershed Protection and Tributary Areas

A combination of improved management practices, land treatment measures, and water control structures will be needed for watershed protection. The most effective cropland practices that are still needed are 2,333,000 acres of conservation cropping

systems, 1,943,000 acres of crop residue use, 993,000 acres of stubble mulching and 77,000 acres of diversions and terraces.

Forest land treatment measures that will be needed include 98,600 acres of erosion control treatment and 2,845 miles of road and trail rehabilitation.

Rangeland practices that will be required include 1.2 million acres seeded to grass, 525,000 acres of brush control and grazing reduction on 1.6 million acres.

Needed structural measures on tributary streams include 9 miles of levees, 552 miles of stream channel improvement, 3 miles of stream channel stabilization, 7,035 of streambank protection, 2,220 miscellaneous other stream structures.

Comprehensive watershed treatment programs comprising land measures and flood control structures on minor tributaries should be applied to 103 watersheds. Total lands subject to flooding in these watersheds that would benefit from the programs amount to 112,500 acres. The land measures and flood control structures in these watersheds are included in the above sub-region totals.

Additional information of the land treatment measures and a schedule of application are included in Appendix VIII.

Streambank Erosion

Treatment of streambank erosion is possible through structural or vegetative means. The use of vegetative protective measures would be confined to smaller streams and headwaters. The average cost of vegetative protection is estimated at \$8,000 per mile. Structural protective measures would be predominantly riprap, having an estimated cost of \$40,000 per mile. An estimated 75 percent of seriously eroding streambank will require treatment prior to 2020 at a total cost of about \$4,500,000.

Flood Plain Zoning

The development of comprehensive land use plans and passage of zoning ordinances including flood plain restrictions by Stevens, Okanogan, Chelan, Lincoln, Grant, and Franklin counties would be effective in reducing future damages resulting from urban expansion. As noted previously, no such zoning ordinance has been enacted.

Stevens County

On the Colville River the two major communities of Colville and Chewelah are established on relatively high ground at least half a mile from the river. There have been no significant urban flood damages and, as community population has been declining slightly, increased urban damages are not anticipated. However, flood plain zoning would encourage utilization of existing adjacent high ground should growth occur at some later time.

Okanogan County

Several communities on the Okanogan River are located largely or partially within the flood plain, making zoning a necessity if increased damages resulting from growth are to be prevented. This is particularly so in the case of Omak as well as Okanogan, Malott, and Tonasket. All of these communities are adjacent to higher ground on which expansion could take place. Oroville, however, on low land between the Okanogan and Similkameen Rivers, and Riverside appear confined to flood-susceptible situations where flood-proofing regulations would be more practicable than zoning requirements.

Communities on the Methow River are small and have stable populations. Flood plain zoning probably would be incidental to any comprehensive land use plan developed by Okanogan County.

Chelan County

Flood plain zoning on the Wenatchee River can be of importance chiefly at Cashmere, a gradually growing community which has partial protection by levee. Zoning at Cashmere and Leavenworth would encourage use of available higher ground instead of expansion toward the river. Within the city of Wenatchee zoning would provide developers with a means of recognizing the hazards in occupying the watercourses of Canyons 1 and 2.

Flood plain zoning on the Chelan and Entiat Rivers is not an urgent necessity, but would be incidental to any Chelan County comprehensive land use plan.

Lincoln County

The towns of Odessa and Wilbur have flood problems. Both towns are growing, and both are adjacent to higher ground. Flood plain zoning would encourage utilization of this higher, flood-free land.

Grant County

The town of Wilson Creek lies at the junction of Crab Creek and Wilson Creek on land having partial levee protection. Population is static, but should expansion occur, flood plain zoning would encourage use of higher ground away from both streams. Moses Lake is situated on a low bluff along the lake about 1 mile downstream from the mouth of Crab Creek. Population growth has leveled off, but should growth occur in the future, flood plain zoning would help developers avoid the flood-susceptible lands on each side of the downstream end of Crab Creek. Ephrata is growing steadily, generally on the plentiful high ground away from the main highway. Flood plain zoning would point out the hazards of attempting to occupy the flood plain between the large irrigation canal and the highway.

Franklin County

An immediate need exists for flood plain zoning in Franklin County to avoid flood damages which could result from unregulated occupation of Esquatzel Coulee. The growing town of Connell within the coulee has partial levee protection and the community of Mesa, partly located on the coulee floor, is subject to flood damages. Zoning would indicate those parts of the coulee suitable for urban development.

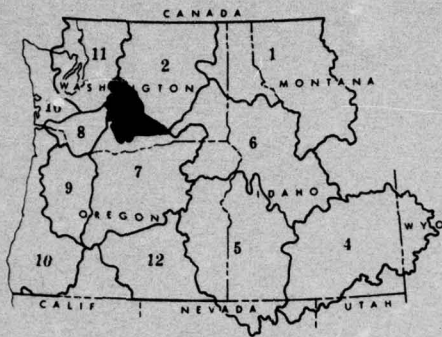
Future Damages Avoidable by Zoning

Wherever an effective and enforced flood plain zoning ordinance is established, any future increase in damage of new construction by flooding can be avoided. This increase, without zoning, may be assumed roughly proportional to the projected population increase in the subregion times change in per capita income.

Table 25 shows the approximate amount by which future urban and transportation average annual damages in table 23 could be reduced through immediate flood plain zoning.

Table 25 - Future Annual Damages Avoidable by Zoning, Subregion 2

<u>Location</u>	<u>1980</u>	<u>2000</u> (Dollars)	<u>2020</u>
Okanogan River	100,000	484,000	1,520,000
Wenatchee River	45,000	218,000	685,000
Canyons 1 and 2	131,000	630,000	1,980,000
Crab Creek	47,000	235,000	730,000



LOCATION MAP

W 20-077000

SUBREGION 3

YAKIMA

GENERAL

Location and Extent

Subregion 3 comprises the Yakima River Basin which lies on the east slope of the Cascade Range and is tributary to the Columbia River. The basin, roughly a triangle of 6,062 square miles, is bounded on the west by the Cascade Range, on the north by the Wenatchee River Basin, and elsewhere by comparatively narrow divides separating it from the main stem drainage of the Columbia.

Topography

The subregion is almost entirely mountainous or hilly, from the 7,000 to 8,000-foot peaks in the Cascades on the west to the encircling ridges with crests of 6,000 feet on the south and 4,000 feet on the northeast. Toward the southeast the ridges flatten somewhat to form rolling plateaus which fall away on each side to the floor of the Yakima and Columbia River valleys. For much of its length the Yakima River flows through well-marked canyons. The major river valley begins a few miles downstream from the city of Yakima and ends in the vicinity of Prosser. Known as the Yakima Valley, it is about 50 miles long and 12 miles wide. Elsewhere in the basin are five other smaller valleys; a strip 1 to 2 miles wide and 20 miles long from Easton past Cle Elum to Teanaway; the 10 by 20-mile Kittitas Valley along the Yakima River at Ellensburg; the valley in the immediate vicinity of Yakima and Selah; a valley 1 to 2 miles wide along the lower 15 miles of the Naches River; and the valley in the vicinity of Richland at the mouth of the Yakima River.

Climate

The summer climate is hot and dry, typical of the continental type. Winters are moderately cold and cloudy, due primarily to the maritime influence of the prevailing westerly circulation from the Pacific Ocean. Approximately 75 percent of the annual precipitation occurs during the period October through March.

Annual precipitation decreases from more than 100 inches in the Cascade Range to less than 7 inches in the lower elevations near the mouth of the Yakima River. Normal annual snowfall in excess of 300 inches falls on the higher slopes of the Cascade Range with the lower valleys receiving 15 to 20 inches. Winter temperatures normally range from near 20°F. at night to near 30°F. in the daytime, but temperatures of 0°F. or below can be expected about every other year in January or February. The lowest recorded temperature, -38°F., occurred at Bumping Lake in the Cascade Range. Normal summer temperatures reach 90°F. during the daytime but cool rapidly to near 60°F. at night, due to the very dry air. Temperatures exceeding 100°F. are not uncommon and a few readings over 110°F. have been recorded. A high of 114°F. has been recorded at Benton City.

Economic Development

The 1965 population was estimated to be 236,700. The major portion is concentrated along the lower reaches of the Yakima River in Yakima and Benton counties. The largest cities were Yakima and Richland with populations of 45,100 and 26,000. Other important cities and their 1965 populations are: Ellensburg, 8,625; Sunnyside, 6,208; and Toppenish, 5,667.

The subregion's water and land resources provide the base for its outstanding agricultural and forest products. The principal economic activities are farming, logging and lumbering, and processing of fruit and vegetables.

The interstate highway system, U. S. highways, and several State highways which serve this area provide excellent contact to the populous Puget Sound area. Railroads and commercial air service provide contact with the rest of the region and the Nation. Although there is no commercial navigation on the Yakima River or its tributaries, port and terminal facilities in the nearby Tri-City area provide easy access to this mode of transportation.

Streams

From Keechelus Lake in the Cascades near Snoqualmie Pass, the Yakima River flows southeast about 215 miles to join the Columbia River near the head of Lake Wallula (McNary Dam reservoir), 10.5 miles upstream from the mouth of the Snake. The Naches River, the Yakima's largest tributary, heads in the Cascades, flows southeasterly, and reaches the main river immediately upstream from the city of Yakima. The Naches flows mainly

through narrow canyons until joined by the Tieton River 15 miles upstream from the Yakima.

Table 26 gives the streamflow characteristics of these and other major streams in the subregion:

Table 26 - Streamflow Characteristics, Subregion 3

Stream	Total Drainage Area	Gage Location	Gage Drainage Area	Flow in cfs		
	Sq. Mi.		Sq. Mi.	Average ^{1/}	Maximum ^{2/}	Minimum ^{2/}
Yakima	6,062	Parker	3,668	1,894	65,000	4
Naches	1,120	Naches	941	1,478	32,200	1
Bumping	193	Nile	71	288	5,180	0
Tieton	298	Tieton Dam	187	495	8,450	0
Cle Elum	222	Roslyn	203	911	18,700	0
Teanaway	205	Cle Elum	200	374	4,330	1

^{1/} Regulated values for base period (1929-1958), 1970 conditions.

^{2/} Observed values for period of record.

Flood Characteristics

Floods in the Yakima Basin occur most often in the spring or early summer as the result of melting snow in the mountains and foothills. These floods are characterized by slow rise and long duration of flows. Melting may be aggravated by warm rains and river stages increased by ice and debris jams. Flooding from rainfall occurs usually in November or December after fall precipitation has replenished ground water reserves and saturated the ground. Heavy rainfall, especially if accompanied by warm winds and some snowmelt, then produces winter floods. Winter flood crests are reduced by reservoir storage as flooding occurs after the irrigation season when storage is available. However, these reservoirs control only a small portion of the entire drainage area, and the space may not be available for the second winter flood if two occur.

HISTORY OF FLOODING

Major floods are listed in table 27. Discharges shown are those actually measured at the time of the flood, but the damages are those which would occur if the flood were repeated under present day economic conditions and price levels.

Since 1862, 16 floods are known to have occurred on the Yakima River and tributary streams, three of the most severe taking place in November 1906, December 1933, and May 1948. (18)

A comparison of flood magnitudes cannot be made on the basis of observed discharge alone because the progressive development of six irrigation storage projects has changed the natural flow regime. The 1906 flood discharge represents natural flow conditions, whereas the 1933 and subsequent flood discharges were modified by the present reservoir system. The December 1933 flood was the largest of record throughout most of the basin. (7) The May 1948 flood was the largest spring flood of record. This flood was not materially affected by storage as the reservoirs were nearly filled when the flood occurred.

Table 27 - Major Floods, Subregion 3

Stream	Date	Peak Discharge cfs	Damages under Present Conditions
Yakima (Above Naches R.)	Nov 1906	41,000	NA
	Dec 1933	32,200	\$2,024,000
	May 1948	27,700	1,719,000
Yakima (Below Naches R.)	Nov 1906	66,000	NA
	Dec 1933	67,000	4,765,000
	May 1948	37,900	2,292,000
Teanaway	Dec 1933	No record	255,000
	May 1948	4,170	4,000
Naches	Nov 1906	21,900	NA
	Dec 1933	32,200	933,000
	May 1948	12,600	220,000

During the 1933 flood, 46,000 acres of land were inundated, and in 1948, 33,000 acres. In both instances, about 7,000 acres were inundated in the Kittitas Valley near Ellensburg and over 60 percent of the total land flooded was along the Yakima River below the city of Yakima. During those floods the swiftly flowing stream tore loose trees, brush and other floating debris which were carried downstream and formed jams. These jams caused stage increases and rapid cutting of new channels with resultant loss of land. Agricultural land was damaged by deposition of floating debris, sand, silt, gravel, and weed seed, and by leaching of the soil. Land was eroded, crops partially or entirely destroyed, and livestock and poultry were lost. Buildings and contents, irrigation and flood control facilities, roads, highways, railroads, fences, power and communication lines, water supply and sewage disposal systems were damaged. Substantial



Vicinity of Ellensburg, Washington, May 1948. (SCS)

losses were sustained from traffic interruptions. Two lives were lost in the 1933 flood and one in the 1948 flood.

PRESENT STATUS

Existing Measures

Flood Control Storage

Six reservoirs having a combined active storage capacity of 1,070,700 acre-feet, have been constructed for irrigation in this subregion. These reservoirs are operated for flood control on the basis of runoff forecasts but, in order to assure an adequate irrigation water supply, are sometimes full when late spring floods occur. Storage is usually available to assist in controlling winter floods. Table 28 shows storage in the six reservoirs. In addition there are 1,000 ponds and small reservoirs with a total capacity of 3,900 acre-feet.

Table 28 - Storage Reservoirs, Subregion 3

<u>Project</u>	<u>River</u>	<u>Active Storage Capacity (acre-feet)</u>
Keechelus Lake	Yakima (above Cle Elum)	157,800
Kachess Lake	Kachess	239,000
Cle Elum Lake	Cle Elum	436,900
Bumping Lake	Bumping	33,700
Clear Lake	North Fork Tieton	5,300
Rimrock (formerly Tieton) Lake	Tieton	198,000
Total		1,070,700

Levees and Channels

Major levees on which information is available are listed in table 29. In addition, local interests have constructed numerous short levees along the Kittitas, Naches, and Yakima Rivers. There are 41 miles of levees on minor tributaries. Many levees

Table 29 - Existing Levees, Subregion 3

<u>Stream</u>	<u>Location</u>	<u>Description and Ownership</u>
Yakima	Cle Elum	Levees totalling 1.4 miles on both banks from Cle Elum to 2 miles downstream. Highway Department, 1965.
Yakima	Ellensburg	Cross levee 1 mile long on left bank 2 miles upstream of Ellensburg. Highway Department, 1967-68. Levees totalling 10 miles on both banks vicinity of Ellensburg, local interests.
Yakima	Yakima	Levees totalling 7 miles on both banks in vicinity of Yakima. Federal Government, 1946-48.
Yakima	Richland	Levees totalling 2.1 miles on both banks, Federal government, 1950-52.
Yakima	West Richland	Levee 1 mile long on right bank. Federal government, 1963.
Teanaway	Mouth to Mile 9	Levees by WPA and local interests, 1935-37.
Minor Tributaries		41 miles of levees.

are riprapped where slopes extend into the river to avoid erosion from high velocity floodflows. This has been done in the vicinity of Cle Elum, Ellensburg, and Yakima; on the Naches River; and along the lower 5 miles of the Teanaway.

No significant channel improvements for flood control have been undertaken on major streams, but 128 miles of channel have been improved on minor tributaries.

Watershed Protection

More than 570,000 acres of cropland have had effective combinations of practices applied which reduce erosion and sedimentation and assist in the reduction of floods. The most effective practices include conservation cropping systems on 249,000 acres, use of crop residue on 208,000 acres, irrigation water management on 176,000 acres, and land shaping on 155,000 acres. Forest land treatment measures include seeding and gully control work on 2,800 acres of badly eroding soils and the rehabilitation of nearly 150 miles of existing and abandoned roads and trails. Rangeland practices of particular significance include seeding 55,000 acres to grass, brush control on 128,300 acres, and controlling excessive grazing on 1.2 million acres.

The soils of Subregion 3 are estimated to have a water holding capacity of at least 1,472,000 acre-feet, an average of 4.58 inches over the entire watershed. This storage is effective in retarding runoff to an extent dependent upon land treatment and weather conditions. Additional information on land treatment is included in Appendix VIII, Land Measures and Watershed Protection.

Flood Plain Regulation Program

A flood plain information study was completed in July 1963 for lands along the Yakima River within Richland. The flood plain consists of approximately 900 acres on the left (east) bank. On the basis of that study the city of Richland has adopted a zoning ordinance, permitting appropriate uses of the flood plain. A flood plain information study for the Yakima River in Benton County provides the basis for a comprehensive land use plan. A flood plain information study covering the Yakima River from Selah to Union Gap and the Naches River in the vicinity of Yakima, was completed in 1970. Flood plain information studies for the Yakima at Ellensburg and Cle Elum are authorized but not scheduled.

Flood Forecasting and Emergency Operations

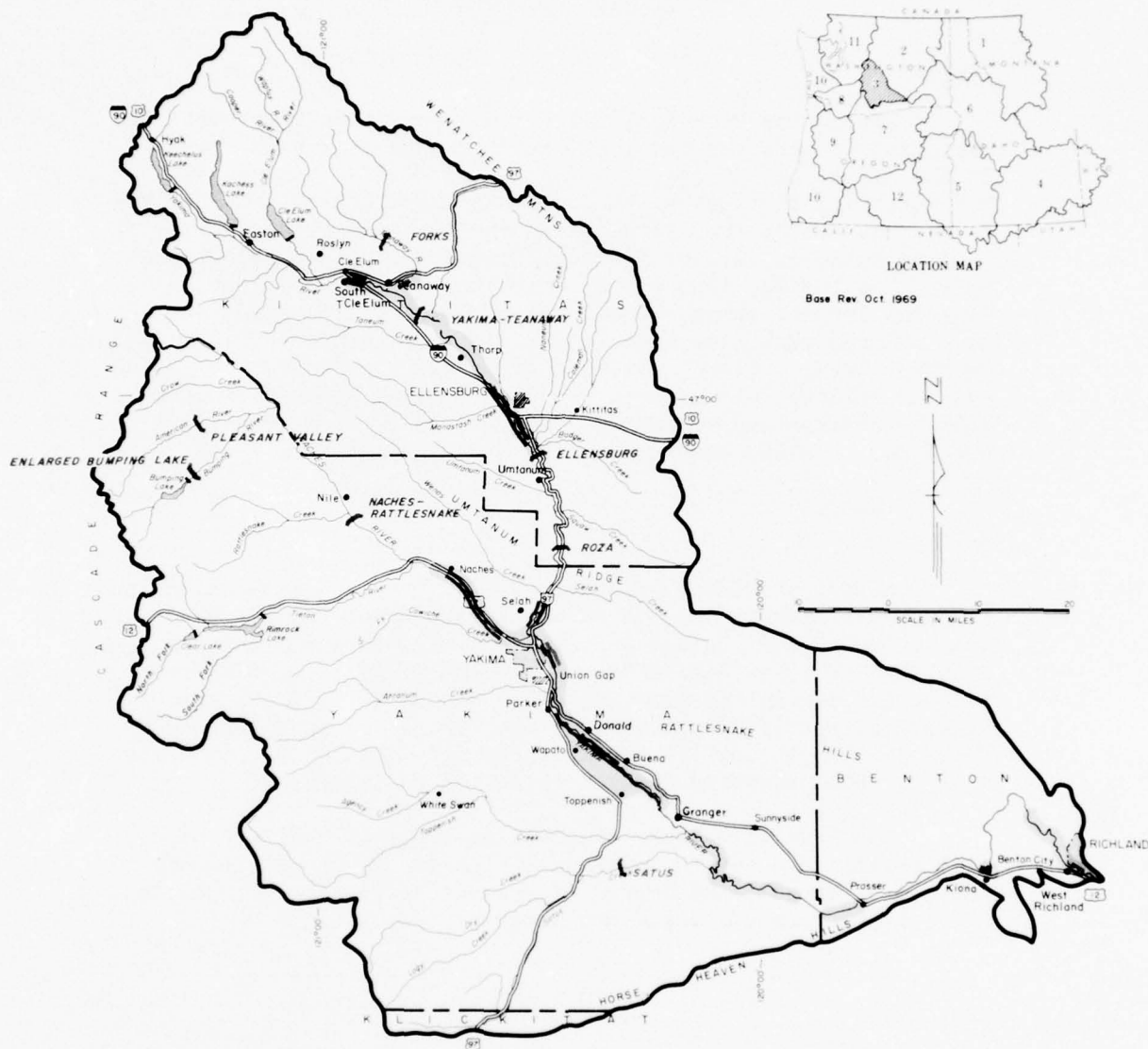
Estimates of impending peak floodflows or stages and the expected time of occurrence are prepared by the River Forecasting Unit at Portland, and disseminated by the Portland River District Office. The River District Office issues emergency and public service teletype bulletins which advise the State Civil Defense Office in Olympia, the national news services, and the Weather Service Office in Yakima. The Yakima Weather Service Office and the Yakima County Civil Defense Directory work together to alert county and city officials, the highway patrol, newspapers, and radio and television stations, including radio stations in Toppenish and Sunnyside. River predictions are not normally made for Ellensburg and Cle Elum but are obtained from the River District by request of Kittitas County officials if desired.

In addition to these channels of information, the Corps of Engineers in Seattle receives flood forecasts directly from the River Forecasting Unit in Portland for the benefit of flood engineers assigned to specific areas for flood emergencies. Table 30 shows these areas, the location of important gages, the zero damage stage and flows at which flooding is considered to begin, and the local officials contacted by flood engineers.

Table 30 - Flood Emergency Areas, Subregion 3

<u>Area</u>	<u>Gage</u>	<u>Zero Damage</u>		<u>Local Contact</u>
		<u>Stage</u> (ft.)	<u>Flow</u> (cfs)	
Yakima River above Teanaway River	Yakima at Cle Elum	11.0	11,000	Kittitas County Engineer
Yakima River-Teanaway River to Ellensburg	Yakima near Ellensburg	1/	1/	Do.
Yakima River-Naches River to Union Gap	Yakima near Parker	9.4	13,500	Yakima County Civil Defense Director and County Engineer
Yakima River-Union Gap to Prosser	Yakima near Parker	9.8	14,700	Do.
Yakima River-Prosser to Richland	Yakima near Parker	9.5	13,500	Do.
Naches River below Tieton River	Naches near Naches	16.5	9,370	Do.

1/ Data being reestablished due to highway construction changing flow characteristics.



EXPLANATION

FLOOD SUSCEPTIBLE AREAS

POTENTIAL STORAGE SITES

EXISTING LEVEES AND CHANNELS

POTENTIAL

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY
**EXISTING & POTENTIAL
FLOOD CONTROL FACILITIES**
YAKIMA SUBREGION 3

1970

FIGURE 9

Accomplishments

Storage

During the December 1933 flood, irrigation reservoirs are estimated to have reduced the peak discharge at Yakima from 83,000 cfs to 54,000 cfs. In the spring of 1949, the basin had the potential for another flood of the magnitude of the May 1948 flood, but due to the operation of the irrigation reservoirs, this potentially serious flood was reduced to one of minor magnitude. For the May 1956 flood, which had the potential of equaling the largest spring flood, the reservoirs are estimated to have reduced peak flow from 36,300 cfs to 19,600 cfs. In December 1959, a flood, which uncontrolled would have been 55,000 cfs (at Yakima), was held to 27,400. Damages prevented during 1959 by storage are estimated at \$2,473,000. In December 1967 and February 1968, storage prevented damages of \$1,929,000.

Levees

Levees provide a high degree of protection at Richland and Yakima. At Richland, 1,335 acres of industrial and residential land is protected against approximately a 100-year frequency flood by levees on the Yakima and Columbia Rivers. At Yakima, protection against 65-year frequency floods (65,000 cfs near Parker) is provided by levees on the Yakima and lower Naches. These levees protect 560 acres of the city and suburbs and from 1948 to 1966 prevented damages estimated at \$888,000.

Non-Federal levees, channel improvements and bank protection prevent damages to railroads, highways, and bridges and provide an unevaluated degree of protection to agricultural lands from spring freshets and minor floods.

Flood Problems

General

Much of the land still subject to flooding lies in narrow strips along streams, but in several areas the flood plain extends from one-half to 1 mile from the riverbank. Flood-susceptible areas include irrigated farmlands and portions of the cities of Yakima, Ellensburg, and Toppenish, and of several small towns.

During floods the swiftly flowing streams overflow their banks and tear loose trees, brush, and other debris which are carried downstream to lodgement areas. Jams of ice, logs, and

brush cause cutting of new channels, loss of farmland from erosion, and stage increases from flow restrictions. Debris deposited on overflowed areas restricts full use of the land until removed.



Wenas Creek during 1956 flood. (SCS)

Yakima River, Cle Elum to Teanaway River

Flows of the upper Yakima River near Cle Elum and the Teanaway River having a 10-year frequency inundate unleveed agricultural land. At approximately a 20-year frequency the levee at south Cle Elum is outflanked, and the levee on the Teanaway River protecting U. S. Highway 10 and the Burlington-Northern Railroad is overtopped. Flooding having a 100-year frequency inundates more than 1,300 acres of land including part of south Cle Elum; and, at slightly greater flows, portions of highways are out of service. Average annual damages in this area amount to \$10,000 of which approximately 50 percent is to urban developments and 25 percent each to transportation facilities and to agriculture.

Yakima River, Teanaway to Naches River

In the Kittitas Valley, flooding characteristics at Ellensburg have been changed by the construction of Interstate 90 in 1967-68 and require further observation. Elsewhere, flooding starts with inundation of unleveed lands near Ellensburg, and agricultural lands and cottages above Selah. At slightly higher

stages, headworks of irrigation ditches near Ellensburg and the Ellensburg water supply pumphouse and wells are damaged. Major floods inundate railroad tracks between Teanaway River and Thorp, the town of Thorp, and considerable agricultural land and portions of roads in the Kittitas Valley and cause serious flooding near Selah. Total acreage inundated exceeds 8,500 acres. Average annual damages amount to \$195,000 with approximately 40 percent urban, 5 percent transportation, and 55 percent agricultural.

Yakima River below Naches River

Flooding along the Yakima River below the confluence of the Naches River begins with 4-year frequency flows inundating unleveed agricultural lands, overtopping low levees, and closing private and county roads. Floods having an 18-year frequency inundate all unleveed bottom lands and portions of highways and cause overtopping of levees between Yakima and Union Gap. Between Union Gap and Prosser 19,000 acres of land are inundated and portions of Toppenish and Donald are flooded. Between Prosser and Richland, 400 acres are inundated. Floods having a 30-year frequency cover the first floors of most of the buildings in unleveed areas between the Naches River and Union Gap; inundate 27,000 acres between Union Gap and Prosser and 1,400 acres from Prosser to Richland; close additional highways; and flood large parts of Toppenish, Wapato, Donald, Buena, and Benton City. At slightly greater flows, levees in this section are overtopped and the sewage disposal plants at Yakima and Union Gap damaged. Average annual damages amount to \$440,000 with approximately 20 percent urban, 10 percent transportation, and 70 percent agricultural.

Naches River

In the Naches Valley, flows having a 6-year frequency inundate 150 acres of orchards and cultivated lands. At slightly greater flows levees near Naches and Painted Rock are overtopped. Floodflows having a 100-year frequency inundate 750 acres of agricultural land and cause general overtopping of levees. Average annual damages amount to \$71,000 with approximately 55 percent urban, 20 percent transportation, and 25 percent agricultural.

Streambank Erosion

Serious erosion occurs on an estimated 150 miles of streambank and the annual land loss is estimated to be 180 acres.

Essentially all of the eroded material remains in the subregion. Present average annual damages including land loss, sedimentation, adverse effects on aquatic life, and recreation are estimated to be \$52,000 nearly all of which is rural.

Upland Areas

More than 73,500 acres of crop, range, and pastureland and 13,500 acres of urban developments in upland areas are inundated by floods on small tributary streams. There is serious streambank erosion on 139 miles of channels in the upstream areas and moderate erosion on 895 miles. Annual land loss is estimated to be 168 acres.

PROJECTIONS AND NEEDS

General Economic Trends

Although the population is expected to grow at a lesser rate than the region as a whole, by 2020 the 1965 population of 236,700 is forecast to increase to approximately 444,000. Most of the growth will be in the larger cities such as Yakima, Richland, Ellensburg, and Toppenish. Agriculture production and employment in processing of food products are expected to increase. Employment growth will occur in manufacturing of chemicals and paper products.

Land Use Trends in Flood Plain

Use of the flood plain will probably continue as at present with opportunities for expansion of most communities available outside the flood plain. An exception to this is Toppenish, which is located on the flat bottom lands of the Yakima Valley with no high ground available. Agriculture on the flood plain is expected to continue producing hay, grains, fruit, nuts, and potatoes.

Flood Damage Projections

Average annual damages for the major flood problem areas under present and future development are shown in table 31. As described in the regional summary, future flood damages have been computed on the basis of projected total personal income for urban and transportation damages and projected crop yields for agricultural damages. However, for the Cle Elum area, which does not

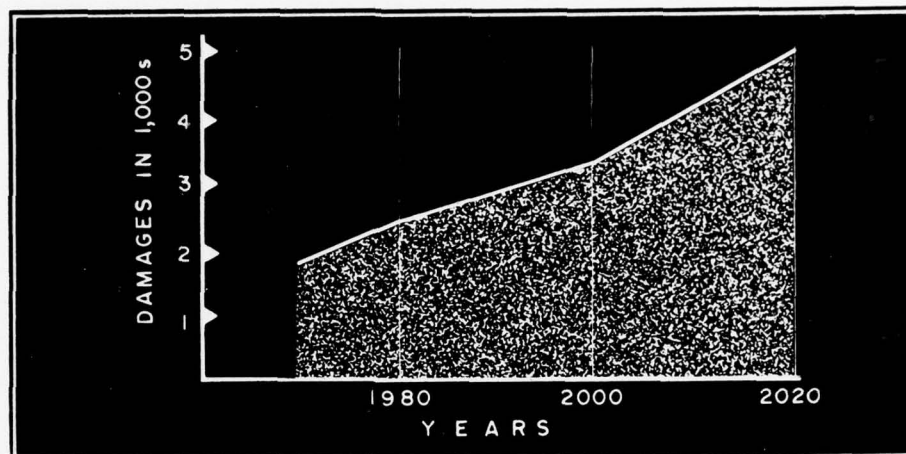


Figure 10. Projected Average Annual Flood Damages, Subregion 3.

Table 31 - Present and Future Average Annual Damages,
Subregion 3

Stream and Area	Damages in \$1,000, 1967 Price Levels					
	Present			1980	2000	2020
	Rural	Urban 1/	Total			
Yakima R. Cle Elum to Teanaway R.	3	7	10	14	20	38
Yakima R. Teanaway R. to Naches R.	108	87	195	287	499	927
Yakima R. below Naches R.	315	125	440	611	955	1,607
Naches R.	16	55	71	116	236	490
Streambank erosion, all basins	52	-	52	56	59	63
Minor tributaries	905	145	1,050	1,302	1,564	1,838
Total	1,399	419	1,818	2,386	3,333	4,963

1/ Includes Residential, Commercial, Industrial, and Transportation.

show active growth, the rate of increase of urban damages was reduced 50 percent.

Summary of Flood Control Needs

Yakima River, Cle Elum to Teanaway River

Levee protection at South Cle Elum and on the Teanaway River is inadequate to protect against any but minor floods. Average annual damages are relatively small but will increase in the future, particularly if expansion in the flood plain is unrestricted.

Yakima River, Teanaway to Naches River

Flooding currently occurs in the vicinity of Thorp, Ellensburg, and Selah. Because of its situation on flat bottom land, unprotected from major flooding, unrestricted expansion of Thorp would multiply damages in the future. Damage to railroad traffic upstream from Thorp may increase gradually. In the Kittitas Valley surrounding Ellensburg, agricultural damages will increase significantly. However, a much greater source of future damage would result from unrestricted growth of the portion of Ellensburg in the flood plain. A similar situation exists at Selah, where most damages now are agricultural.

Yakima River below Naches River

Almost half of the urban damages in the subregion occur along the Yakima River below the Naches, and problems are increasing as the city of Yakima continues to expand onto the flood plain. Toppenish is not growing rapidly but, situated on the flat bottom land of the Yakima Valley, will have greater urban damages with any expansion. The same is true to a lesser degree at Wapato and Buena. Most of the agricultural damages in the subregion are in the Yakima Valley between Union Gap and Prosser, where much of the land has no levee protection. These damages will grow with increased future production.

Naches River

Most of the damages on the Naches River occur at the community of Naches, which lies on the landward side of a major highway along the river. These damages will be much larger in the future if Naches expands towards, instead of away from, the river. Damages to agriculture are moderate but will grow with increased production.

MEASURES REQUIRED TO SATISFY NEEDS

The valley areas of this subregion are highly developed and require both structural and nonstructural measures to achieve the most economic and effective protection from flood damages. The following discussion of the various measures is divided into general categories such as storage, watershed protection, and other means.

Storage

Storage Requirements

Complete control of a 100-year flood such as occurred in December 1933 would require 675,000 acre-feet of suitably located storage. Of this total, 375,000 acre-feet in existing reservoirs (see table 28) would be adequate to control runoff at the respective sites and is normally available when needed on a forecast basis or until the previous year's irrigation depletions are replaced. However, the availability is not assured for late spring floods or in years that have more than one major winter flood such as occurred in December 1964 and January 1965 in much of the Columbia-North Pacific Region. Additional joint-use storage would be needed to assure that space could be available in the existing reservoirs whenever needed for flood control. New storage totalling 215,000 acre-feet on the Yakima below the mouth of the Teanaway and 85,000 acre-feet on the Naches below the mouth of the Bumping River also would be needed to complete the requirement for 675,000 acre-feet of usable flood control storage.

Potential Reservoir Sites

Several comprehensive studies of the Yakima Basin have included examination of storage sites. These studies include the Corps of Engineers Columbia River Report of 1948 (7), the Corps of Engineers Yakima River Basin Report of 1956 (19), a preliminary report on Satus Creek by the Bureau of Indian Affairs, October 1967 (28), and a feasibility report by the Bureau of Reclamation in 1968 on the Bumping Lake Enlargement (31). Potential storage sites based on the above reports are shown on figure 9 and listed in table 32. The item "Average Cost of Storage" in the table was obtained by updating latest available construction cost estimates. This is only an approximation as the actual cost per acre-foot would vary with the height of dam and the actual storage provided.

Nearly all of the needed additional flood control storage on the Yakima could be acquired at any of the three main river sites. Extensive highway and railway relocations would be required. Storage at the Ellensburg or Roza sites would not affect the problems along the upper Yakima River.

The enlarged Bumping Lake Project, planned by the Bureau of Reclamation, would create a multiple-purpose reservoir of 458,000 acre-feet active capacity which would be used for fishery enhancement, irrigation, recreation, and flood control. It would release some space for flood control in the existing reservoirs throughout the basin by providing hold-over storage to replace any irrigation

Table 32 - Potential Flood Control Storage Sites,
Subregion 3

<u>Stream</u>	<u>Site</u>	<u>River Mile</u>	<u>Usable Storage (AF)</u>	<u>Average Cost of Storage (S/AF)</u>
Yakima	Yakima-Teanaway	163	190,000	315
Yakima	Ellensburg	139	215,000	163
Yakima	Roza	123	190,000	425
Teanaway	Forks	12	52,000	252
American	Pleasant Valley	10	73,000	140
Bumping	Enlarged Bumping Lake	19	458,000	79
Naches	Naches Rattlesnake	27	85,000	172
Satus	Satus	15	85,000	152

storage in other reservoirs that was evacuated or not filled in flood control operation. It also would supply much of the needed additional flood control storage in the Naches Valley.

Levees

Sites Previously Studied

Levee protection has been studied at three locations; near south Cle Elum, on the left and right banks near Ellensburg, and on the right bank near Toppenish.

South Cle Elum A levee approximately 4,000 feet long on the right (south) bank of Yakima River to protect south Cle Elum, designed for a flow at the Cle Elum gage of 17,000 cfs, would provide protection against a 30-year frequency flood with the existing operation of upstream reservoirs. Further increasing the height of the levee would involve raising a highway bridge and railway line. Estimated cost of the levee is \$115,000 with annual maintenance costs estimated at \$1,000.

Ellensburg Approximately 20 miles of levees would protect 6,300 acres of agricultural and urban developments. The impact Interstate Highway 90 will have on the project plan has not been fully determined, but an estimate has been made that 4 miles of levee could be eliminated. Levees were designed for a flow at the Umtanum gage of 45,000 cfs, which has a 400-year frequency with existing operation of upstream reservoirs. Estimated cost of the levee system, ignoring effects of Interstate 90, is \$5,700,000. Annual maintenance costs are estimated at \$30,000. Levee construction has received Congressional authorization and will be initiated when funds are available.

Toppenish Levees near Toppenish to protect 13,300 urban and rural acres would begin southeast of Parker on the right bank and extend downstream 18 miles to opposite Granger. These levees were designed for a flow of 75,000 cfs at Yakima, which has a 200-year frequency under existing operation of the upstream reservoirs. A major portion of the protected lands is in the Yakima Indian Reservation. Cost of the levee system is estimated at \$5,130,000, and annual maintenance costs at \$25,000. Interstate Highway 82, currently being constructed, will pass through this area on the right side of the river. Consideration is being given to designing this highway to act as a levee, with flap gates at stream crossings.

Other Sites

Selah Area A levee about 4 miles long on the right (west) bank of the Yakima near Selah would protect approximately 900 acres of land. The cost to provide protection against a flood having a 100-year frequency is estimated at \$1,140,000 and annual maintenance at \$5,000. A levee 3 miles long on the left (east) bank across from Selah would protect an estimated 600 acres of land from a 100-year frequency flood. Estimated construction cost is \$850,000 and annual maintenance \$4,000.

Donald-Buena Area Levees totaling 7.5 miles in length would protect approximately 2,400 acres of land on the left bank of the Yakima River between Donald and Buena against a 100-year frequency flood. Estimated construction cost is \$2,140,000 and annual maintenance \$10,000.

Naches Valley Eleven and one-quarter miles of levees in the Naches Valley on both banks would protect approximately 1,600 acres of land from a 100-year frequency flood. Costs are estimated to be \$3,210,000 total and \$15,000 annually for maintenance.

Benton City Cooperative state-county-city planning is underway to provide levee protection for that part of Benton City between the benchland and the bend in the Yakima River.

Flood Control Channels

There are no indications that improvement of existing channels or construction of diversion channels would be a practicable method for flood control in the Yakima River Basin.

Watershed Protection and Upland Areas

Reduction of flood damages in upland areas will require improved management practices, additional land treatment measures, and more water control structures. The most needed cropland practices are 650,000 acres of conservation cropping systems, 570,000 acres of crop residue use, 375,000 acres of irrigation water management, and 55,000 acres of land shaping. On forest lands needed practices include 50,000 acres of erosion control treatment and 640 miles of road and trail restoration. On rangeland, 105,000 acres need seeding to grass, 810,000 acres need brush control, and grazing should be reduced on 30,000 acres. Needed stream structural measures include 2,700 ponds and reservoirs with 8,400 acre-feet of storage, 50 miles of levees, 450 miles of stream channel improvement, 120 miles of stream channel stabilization, 260 miles of streambank protection, and 340 miscellaneous other stream structures.

Comprehensive watershed treatment programs comprising land treatment and structural measures will be required on 24 watersheds with a total area subject to flooding of 73,200 acres. The works that would be performed on these watersheds are included in the above subregion totals of land treatment and small structural measures.

Additional information of the land treatment measures and a schedule of application are included in Appendix VIII.

Flood Forecasting

Improvements in forecasting techniques and more extensive snow surveys on which to base predictions of runoff from snowmelt would permit more effective use of irrigation reservoirs for flood control.

Flood Plain Zoning

The development of a comprehensive land use plan and the passage of a zoning ordinance including flood plain restrictions by Kittitas, Yakima, and Benton counties would be effective in reducing future damages resulting from urban expansion. As noted previously, only the city of Richland has a flood plain zoning ordinance.

Kittitas County

All sizeable communities on the Yakima River in Kittitas County have adjacent high ground on to which expansion could take place. This is particularly true of Ellensburg which has been growing rapidly and to a lesser extent of Cle Elum which has a static population. Flood proofing measures appear desirable at the small community of Thorp, which is on bottom land half a mile from the river without any adjacent high ground.

Yakima County

The city of Yakima has the greatest potential in the sub-region for future urban damages as a result of growth onto the flood plain even though high ground is plentiful in other directions. Zoning appears essential to counteract this tendency. Zoning would also direct the expansion of Selah and Naches toward higher ground and away from the low areas adjacent to the river. On the other hand, Toppenish, Wapato, and Buena are located on the flat bottom lands of the Yakima Valley with no adjacent high ground. Growth of these communities has been slow and the application of the usual flood plain zoning restrictions may be difficult. Flood proofing requirements may be a more practicable means of minimizing damages to future developments.

Benton County

The chief problem of flood plain use in Benton County is at Richland, and this has been covered by a zoning ordinance. Benton City, located on a bench at a bend in the Yakima River, has spread onto the lowland riverward of the bench. Flood plain regulations and flood proofing are desirable even though population at present is static.

Damages Avoidable

Table 33 shows the approximate amount by which future urban and transportation average annual damages in Subregion 3 could be reduced through immediate flood plain zoning.

Table 33 - Future Damages Avoidable by Zoning,
Subregion 3

<u>Location</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
Yakima River, Cle Elum to Teaaway River	\$ 1,000	\$ 4,000	\$ 13,000
Yakima River, Teaaway River to Naches River	21,000	107,000	330,000
Yakima River, below Naches River	30,000	154,000	480,000
Naches River	<u>13,000</u>	<u>68,000</u>	<u>210,000</u>
Total	\$65,000	\$333,000	\$1,033,000



LOCATION MAP

4 20-0000000

SUBREGION 4

UPPER SNAKE

GENERAL

Subregion 4 includes all the area draining into Snake River above King Hill, Idaho. In shape, the area is roughly rectangular, with its longest dimension in an east-west direction. Maximum length is about 300 miles and maximum width about 165 miles. It has an area of 35,857 square miles, of which 28,821, 5,139, 1,521, and 376 square miles are located in Idaho, Wyoming, Nevada, and Utah, respectively.

Topography

Land forms of strong and varied relief consisting of mountains, mountain valleys, and plateaus mark this subregion. The subregion is nearly surrounded by mountains with spur ranges thrusting into the area to form boundaries of individual drainage basins. The Snake River flows from the subregion to the west at elevation 2,500. Valley floors range in elevation from 3,500 feet near Gooding to 4,500 feet at American Falls and 6,000 feet in the Jackson Hole area. The mountains around the periphery of the subregion range in elevation from 5,000 feet in the lower passes to more than 10,000 with a few peaks rising to about 12,000. The semi-arid Snake River Plain occupies the center one-third of the subregion and lies at elevations from 4,000 to 5,000 feet.

Climate

A more complete description of the climate of the subregion and its effects on water resources is given in Appendix V. The principal factors which produce or influence flood flows are distribution of precipitation and temperature fluctuations. Average annual precipitations range from less than 8 inches at lower elevations of the Snake River Plain to in excess of 50 inches in the mountains of western Wyoming where exposures are favorable for precipitation due to orographic lifting. Over most of the subregion, precipitation is heaviest in the winter and lightest in summer and early fall. However, in the mountainous areas of the eastern part of the subregion, precipitation is more uniformly distributed and fairly heavy rains occur in May and June during the period of maximum snowmelt. Much of the warm

weather precipitation comes from thunderstorms, some of which assume cloudburst proportions and cause severe local flooding. Average annual snowfall is nearly 200 inches at Island Park reservoir near Yellowstone Park, 150 inches at the high valley stations in Wyoming, but only about 20 inches at the western edge of the subregion. Snow occasionally accumulates to a depth of 12 inches over much of the lowlands and such accumulations are sometimes melted by warm winter rainstorms and cause lowland flooding.

Temperatures are influenced by both continental and maritime airmasses and show a wide range within the subregion. Extremes recorded over a long period have been 113°F. at Hazelton, Idaho, and -63°F. at Moran, Wyoming. Occasionally during winter, arctic airmasses cover all or portions of the subregion and sub-zero nighttime temperatures occur. Such a cold snap may be displaced by a warm maritime airmass in which case flooding may result from rainfall and low-level snowmelt and may be complicated by ice flows.

Economic Development

An estimated total of 302,000 (1965) people reside in the subregion. A generalized distribution of the population is 60 percent rural and 40 percent urban. Almost all of the population is located in the areas of developed irrigated agriculture, which is the dominant economic activity. Nearly 98,000 persons were employed in the subregion in 1960 of which approximately 21,900 were engaged in agriculture and 4,800 in food processing industry. Scenic, sport fishing, hunting, and other recreational attractions have boosted tourism to another basic job-furnishing activity. The principal cities are Idaho Falls, Pocatello, and Twin Falls, Idaho, with 1960 populations of 33,161, 28,534, and 20,126, respectively. Nine other cities had populations in excess of 2,500 and 26 between 500 and 2,500. There were 45 towns with populations less than 500. About 27 percent of the land is privately owned; an approximate pattern of land use is: agricultural land - 19 percent; range and forest area - 70 percent; and miscellaneous areas - 11 percent. The subregion is served by the main line and branch lines of the Union Pacific Railroad Company; two commercial airlines; Interstate Highways 80N (US 30) and 15 (US 91); US Highways 20, 26, and 93; and numerous state and county roads.

Streams

The Snake River originates near the Continental Divide just inside the southern boundary of Yellowstone National Park. From

its upper end the river flows through the subregion for a distance of about 500 miles in a general southwesterly direction. It is contained successively in Jackson Lake, Palisades, and American Falls Reservoirs, and Lakes Walcott and Milner. The river flows through a broad flood plain in the Jackson Hole area of Wyoming, a narrow mountain canyon from the lower end of Jackson Hole to the upper end of Palisades Reservoir, a broad canyon from Palisades Dam to the vicinity of Heise, Idaho, and another active flood plain from Heise to Milner. Below Milner Dam, the river drops into a canyon cut through lavas of varying degrees of hardness. Mean flow on Snake River at Heise, Idaho, as shown in Appendix V is 6,489 cfs. Observed flows vary from a maximum of 60,000 cfs, which was a result of release of temporary storage when a landslide on Gros Ventre River washed out, to a minimum of 460 cfs. The principal tributary streams in this subregion are listed in table 34.

Table 34 - Streamflow Summary for Selected Sites, Subregion 4

Stream	Total Drainage Area (Sq. Mi.)	Snake River Mile	Gage Location	Gage Drainage Area (Sq. Mi.)	Flow at Gaging Station, cfs ^{1/}		
					Mean	Max.	Min.
Pacific Creek	160	998	Moran, Wyo.	160		3,470	23
Buffalo Fork	380	996	Moran, Wyo.	355		5,960	84
Gros Ventre	683	968	Kelly, Wyo.	622		6,220	101
Hoback	572	944	Jackson, Wyo.	564		6,160	90
Greys River	454	922	Alpine, Wyo.	448		5,200	111
Salt River	870	917	State Line	829		3,520	217
Henry's Fork	3,010	837	Rexburg, Ida.	2,920	1,512	11,000	183
Blackfoot	1,110	751	Blackfoot, Ida.	1,295 ^{4/}		1,710	0
Portneuf	1,400	736	Pocatello, Ida.	1,250	154	2,990	0.4
Raft River	1,300	692	Bridge, Ida.	412		1,090	0.8
Goose Creek	1,100	654	Oakly, Ida.	633		3,240	0
Salmon Falls Cr.	2,100	587	Buhl, Ida.	2,100		298	56
Camas Creek	480	2/	Camas, Ida.	400		1,220	0
Beaver Creek	510	2/	Camas, Ida.	510		229	0
Medicine Lodge Cr.	270	2/	Argora, Ida.	165		361	4.0
Little Lost River	760	2/	Howe, Ida.	703		450	4.1
Big Lost River		2/	Arco, Ida.	1,410	278	2,330	0
Big Wood River	3,070	571	Gooding, Ida.	2,990	198	8,860	0
Snow River		862	Heise, Ida.	5,752	6,489	60,000 ^{3/}	460
Snow River		640	Milner, Ida.	17,180	1,545	40,000	2
Snow River		546	King Hill, Ida.	35,800	8,590	47,200	1,250

^{1/} Where available.

^{2/} Does not reach Snake River as surface flow.

^{3/} Result of release of temporary storage when a landslide on Gros Ventre River washed out; flood of June 1894 was probably as great.

^{4/} Includes Sand Creek, which is diverted into Blackfoot.

The portion of the Snake River Basin that extends from the headwaters of Snake River downstream to the vicinity of Heise, Idaho, contains the principal tributary streams of Pacific Creek, Buffalo Fork, Gros Ventre River, Hoback River, Grays River, and Salt River. The area consists of 5,750 square miles of generally rugged mountainous terrain located in western Wyoming and the extreme eastern portion of Idaho.

Henrys Fork, the largest tributary of Subregion 4, rises near the Continental Divide in the Centennial Mountains west of Yellowstone National Park. Its basin lies in eastern Idaho and extreme western Wyoming. With the exception of the rugged western slopes of the Teton Range bordering the southeastern segment of the basin, the mountainous areas of Henrys Fork Basin are only moderately rough. The stream in its lower reaches flows along the western edge of a relatively broad, flat plain.

The drainage area between Heise and Milner Dam, with the exception of Henrys Fork Basin, includes the principal tributary streams of Blackfoot River, Portneuf River, and Goose Creek. This area contains more than 8,400 square miles.

An area lying north of the Snake River between Henrys Fork and Wood River Basins has no surface outflow to Snake River. Principal streams in this area are Camas Creek, Beaver Creek, Medicine Lodge Creek and Big and Little Lost Rivers. The almost 10,000 square mile area includes terrain varying from barren plains along the southeast to rugged mountains in the northwest part. The runoff from this area enters the ground water reservoir which feeds the Thousand Springs, located along the Snake River Canyon between Milner and King Hill.

Main tributaries entering Snake River between Milner Dam and King Hill are Salmon Falls Creek and Big Wood River. The area contains over 8,600 square miles. Additional information on streams and streamflow characteristics is included in Appendix V.

Flood Characteristics

Floods in Subregion 4 are caused by three distinct phenomena: spring melt of headwater snow, which may be augmented by rain; localized flooding from high intensity summer precipitation; and winter rain augmented by low elevation snowmelt which may be compounded by frozen ground. Floods in the area above Heise and on the Henrys Fork, Willow Creek, and Blackfoot Rivers are generally the result of spring snowmelt. These floods generally last for periods of several days to several weeks, with their concentrations and magnitudes partly dependent on temperatures and precipitation during the runoff season. Peak flows usually occur among a succession of high fluctuating flows and often are only slightly greater in magnitude than the high flows of several days duration. However, flooding during the winter months caused by ice jams and comparatively low flows has occurred in the lower reaches of these streams or on their tributaries. Teton River, tributary to Henrys Fork, in particular has flooding caused by ice. Snake

River in the reach from the Henrys Fork confluence to American Falls Reservoir is also subject to localized ice jam flooding.

Flood peaks caused by winter rains are more characteristic in the Portneuf River basin, although more than half of the flood peaks at Pocatello have come primarily from high elevation snowmelt.

Maximum floods on the tributaries south of Snake River and west of the Portneuf basin have been all three types. However, it appears that the greatest potential for major floods in the lower reaches of these streams is from winter rain on frozen ground augmented by snowmelt.

In the Little Wood River basin from Carey to the confluence with the Big Wood River, nearly all flooding is caused by moderately high discharges when the river channel is severely restricted by ice. In the upper areas of the Wood River basin, particularly above Magic Reservoir, floods are generally from spring snowmelt runoff.

Table 35 shows pertinent data on bankfull and major flood stages and flows at key locations throughout the subregion.

Table 35 - Bankfull and Major Flood Stages, Subregion 4

Stream	Station	Bankfull			Major Flood		
		Stage (ft.)	Q (cfs)	Freq. (yr.)	Stage (ft.)	Q (cfs)	Freq. (yr.)
Snake R.	Moran	1/	6,000	1.2 2/	1/	10,000	4.8 2/
Snake R.	Heise	7.2	20,000	3.5 2/	8.3	26,000	50 2/
Henrys Fork	Rexburg	7.8	4,500	1.3	9.1	7,000	3.3
Portneuf R.	Pocatello	6.2	700	2.5	7.0	1,100	6.7
Big Lost R.	Mackay	3.4	900	1.2 2/	5.8	2,640	25 2/
Big Wood R.	Gooding	7.2	2,000	1.9 2/	11.5	8,000	29 2/
Little Wood R.	Shoshone	1/	800	7.7 2/	1/	2,000	37 2/

1/ Not available.

2/ Regulated frequencies.

HISTORY OF FLOODING

Damages in Subregion 4 during recent floods are summarized in table 36. Descriptions of significant floods by appropriate stream reaches follow.

Snake River

Flood damages on the main stem in this subregion for the most part are confined to the flood plains in the vicinity of Jackson, Wyoming, and in the reach from Heise to American Falls Reservoir. The bankfull capacity of Snake River throughout the Jackson Hole area is about 6,000 cfs, and flows exceed this amount

in 5 out of every 6 years. Flood peaks higher than that of June 1964, for which damages were recorded, occurred in 1894, 1904, 1909, 1918, 1927, and 1943, but no records of damages during these other floods are available.

Flooding along Snake River from Heise to American Falls, Idaho, has been experienced frequently. The maximum flood occurred in 1894 with estimated flows of 65,000 cfs and 77,000 cfs at Heise and Milner Dam, respectively. Although no record of dollar damages for the 1894 flood are available, it is known that there were substantial acreages inundated and that crops were destroyed. (7)

Table 36 - Flood Damage Survey Data, Subregion 4

Date	Stream & Gage Location	Area Flooded (Acres)	Peak Dis- charge (cfs)	Damages 1/ \$	Damages 1/ Prevented \$
Jun 48	SNAKE R, Heise, Ida	2/	30,500	377,500	2/
May 52	Heise, Ida	2/	26,800	268,000	2/
Jun 56	Heise, Ida	2/	33,300	730,000	5,900,000
Jun 64	Jackson, Wyo	2/	15,500	66,300	2/
Jun 56	Teton R, St. Anthony, Ida	1,500	3,790	55,000	0
Jun 57	St. Anthony, Ida	2,500	4,660	100,000	180,000
Feb 62	Henry's Fk, 3/ Rexburg, Ida	10,900	7,100	704,000	345,000
Feb 63	St. Anthony, Ida	4,620	5,600	165,000	2/
Jun 64	Rexburg, Ida	6,000	11,000	204,800	4,000
Feb 62	Willow-Sand Cr., Ririe	56,500	5,080	3,305,000	763,000
May 57	Blackfoot R, Blackfoot, Ida	2/	1,040	100,000	50,000
Feb 62	Blackfoot, Ida	6,800	2,050	144,000	305,000
May 52	Portneuf R, Pocatello, Ida	4,340	1,050	108,400	72,000
Feb 57	Pocatello, Ida	2/	970	40,000	0
May 57	Pocatello, Ida	2/	800	35,000	0
Feb 62	Pocatello, Ida	8,400	2,990	3,485,000	343,000
Feb 63	Pocatello, Ida	8,300	2,470	2,580,000	270,000
Dec 64	Pocatello, Ida	1,476	1,040	263,700	85,000
Feb 62	Goose Cr, Oakley, Ida	2/	3,240	30,000	2/
Feb 62	Salmon Falls Cr, Contact, Nev	2/	2,300	13,000	2/
Feb 46	Camas and Beaver Creeks	2/	2/	280,000 4/	2/
Jun 65	Big Lost R, Chilly, Ida	18,200	3,520	1,064,000	100,000
May 67	Chilly, Ida	14,000	4,420	730,100	309,350
May 52	Big Wood R, Gooding, Ida	6,012	6,600	622,000	2/
May 56	Hailey, Ida	4,600	4,640	210,000	0
Feb 62	Gooding, Ida	2/	6,000	154,000	1,149,000
Feb 63	Gooding, Ida	2/	6,300	275,000	460,000
Dec 64	Gooding, Ida	1,715	8,860	372,600 5/	1,815,000
Jan 65	Gooding, Ida	2/	5,080	24,000 5/	2/
May 65	Gooding, Ida	1,375	3,000	360,000	15,000
May 43	Little Wood R, Gooding, Ida	2/	250 6/	146,000	2/
Dec 64	Carey, Ida	2,534	2,400	150,700	2/
Jan 65	Carey, Ida	2/	140	29,600	2/

1/ Values shown are basin-wide and except as noted, are based on development and price levels at the time of the flood.

2/ Not available.

3/ Includes Teton R.

4/ 1957 price level.

5/ Data for Little Wood R. not included.

6/ Flooding due to ice in channel.

The second largest known flood in the subregion was that of 1918, during which the maximum discharge near Heise, Idaho, was 52,000 cfs. In 1927, a flood peak of 60,000 cfs on the Heise gage resulted from release of temporary storage when a landslide on Gros Ventre River washed out, but it diminished rapidly farther downstream. The peak of this flood was not determined at other locations.

Henrys Fork

Flood damages have occurred along the lower 22 miles of Henrys Fork and along Teton River near Rexburg, Idaho. The bankfull capacity of this reach of Henrys Fork is approximately 6,000 cfs. The 1894 flood, estimated peak 11,500 cfs, was the largest historical flood on the stream but was almost equalled in June 1964 by a flow of 11,000 cfs. Damages along Henrys Fork were estimated at \$110,000. (23) In February 1962, stages of a flood which had a peak flow of 7,100 cfs were augmented by ice jams, and damages in the magnitude of the 1964 flood resulted. (26)

Floods on Teton River are almost an annual occurrence. Major floods occurred in June 1927, June 1957, February 1962, and February 1963 with recorded peak flows of 9,490 cfs, 8,680 cfs, 7,000 cfs, and 7,280 cfs, respectively. Of these, the flood of February 1962, even though the smallest, was the most damaging because ice gorges accompanied peak flows. Damages were estimated to be \$589,000. (22)

Willow Creek - Sand Creek Basin

Flood damages occur along the reach of Willow Creek from near Ririe to the mouth. The largest flood of record was 5,080 cfs in February 1962. Ice conditions in the channels contributed heavily to the \$3,305,000 in damages. (22)

Blackfoot River

February 1962 produced a record flood in Blackfoot River of 2,050 cfs which inflicted damages estimated at \$144,000. Most of the damages occurred between the Blackfoot Diversion Dam, which is located just upstream from the City of Blackfoot, and the mouth of the river. (22) The normal bankfull channel capacity of 500 cfs has been exceeded eight times since 1921.

Portneuf River

The February 1962 flood, with a peak flow of 2,990 cfs at Pocatello, was the largest historical flood on the Portneuf River. (22) It inflicted damages in the basin estimated at \$3,485,000 most of which occurred in residential and commercial areas of Pocatello, Inkom, Lava Hot Springs, and Bancroft. Prolonged inundation substantially increased the magnitude of the damages. Damages in rural areas consisted mainly of washed out railroads and highways where culvert and bridge capacities were insufficient. Erosion and siltation damages to farms and crops were relatively low because the ground was frozen at the time of the flood. Roads, bridges, and croplands were damaged. Side drainages deposited debris in Marsh Creek and reduced the channel capacity. Ice was not a significant factor. A similar flood in February 1963 had a peak flow of 2,470 cfs and caused damages estimated at \$2,580,000. (21) Since 1897, seven flows in excess of the bank-full capacity of 1,000 have occurred at Pocatello.

Goose Creek

The February 1962 flood peak of 3,240 cfs on Goose Creek was almost twice as large as the next largest recorded peak flow. Damages resulting from the 1962 flood were estimated at \$30,000. (22) Damages below the Lower Goose Creek Reservoir were negligible.

Mud Lake Subbasin

Camas and Beaver Creeks are sources of surface inflow to Mud Lake, which has no outlet other than irrigation canals, evaporation, and seepage. Lands along Camas Creek near the lake and along the south side of the lake have flooded in the past but are protected by locally-constructed levees. Flooding resulted from high flows and levee failures in 1932, 1945, and 1946. The 1946 flood inundated 4,600 acres, consisting of 3,200 acres of cropland, 1,200 acres of pasture, and 200 acres of farmsteads and roads, and caused \$280,000 damages. Since 1946, the levees have been improved, and higher levels in Mud Lake, notably in 1952, have not caused significant flood damage.

Big Lost River

The flood of May through July 1967 on Big Lost River, with a peak flow of 4,420 cfs, exceeded the previous peak of 57 years of record, 3,960 cfs in June 1954. In 1967, overbank flows inundated about 7,000 acres. In addition, the rise of the ground

waters flooded another 7,000 acres, damaged crops, contaminated wells, and flooded basements. It is estimated that the Big Lost River Valley suffered \$730,100 flood damages. An additional \$309,350 in damages were prevented by emergency activities. A total of 20 floods in 54 years have had discharges from the Mackay Reservoir exceeding the bankfull capacity of 1,500 cfs.

Big and Little Wood Rivers

Flood damages in the Wood River Basin have occurred primarily in a reach extending from Ketchum to Bellevue, near Gooding by Big Wood River, and at Carey, Shoshone, and Gooding by Little Wood River. The more frequent flood problems and damages, particularly at Gooding, have been due to floods which occur from ice formation in the channel. For instance, the flood at Gooding in 1943 had a peak flow of only 200 cfs but caused an estimated \$146,000 damage. This flood was a direct result of ice in the channel severely constricting the flow.

The largest flood of record on the Little Wood River at Carey occurred in April 1938 and had a peak of 6,000 cfs. This flow was caused partly by failure of a reservoir on a minor tributary, but it is estimated that a peak of 2,900 cfs, still larger than any other known discharge, would have occurred without the failure.

The flood of December 1964 on Big Wood River had a peak discharge of 8,860 cfs at Gooding and was the largest recorded. It inundated 1,700 acres and caused extensive damage in Camas Creek valley and from Shoshone downstream. Total damages were estimated to be \$372,600. The same flood inundated 2,500 acres in the Little Wood drainage and caused damages totaling \$150,700 including extensive damages in Carey Valley. (23)

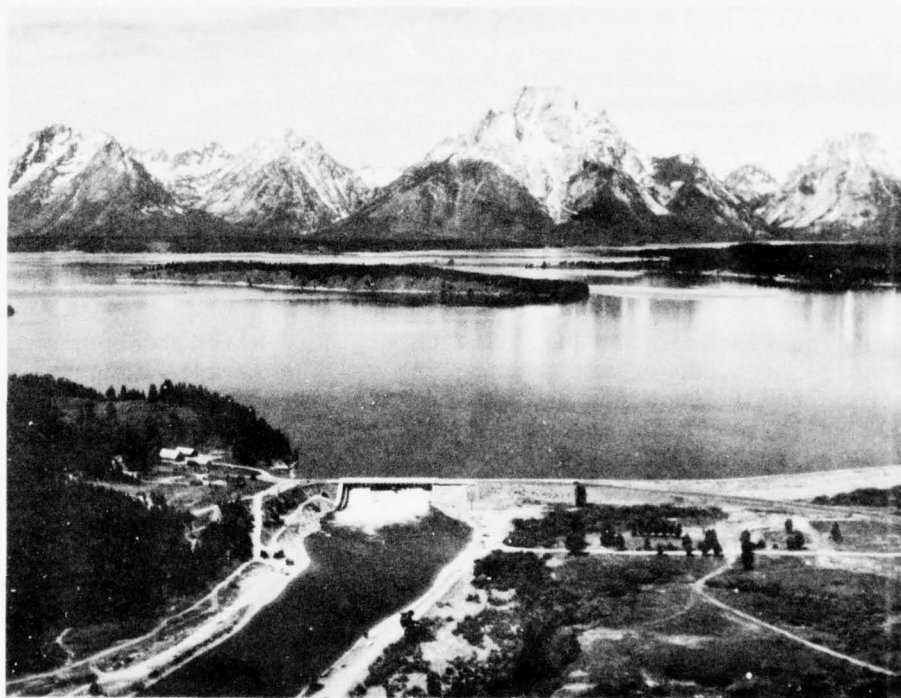
PRESENT STATUS

Existing Measures

Flood Control Storage

Five reservoirs in Subregion 4 (including two under construction) are regulated for flood control on a forecast basis. These projects are listed in table 37; their total usable storage is 2,375,000 acre-feet. About 73 percent of the total usable storage or 1,726,000 acre-feet is normal flood control storage. In addition, 22 reservoirs and about 3,900 farm ponds that function for purposes other than flood control provide significant reductions in flood damages through informal flood control

operation or incidental storage of floodwaters. These projects have an aggregate storage capacity of 3,160,000 acre-feet and range in capacity up to 1.7 million acre-feet at American Falls Reservoir. Table 38 lists these reservoirs. As much as 600,000 acre-feet of storage in American Falls Reservoir has been used for flood control, and plans for reconstruction of the facility provide for using this amount of storage jointly for flood control on a forecast basis. Some of the other large reservoirs have also been operated informally to reduce damages during major floods; and as stream forecasting is improved, it is expected that appropriate criteria will be developed to increase the space available for storage of floodwaters in reservoirs originally constructed for single-purpose uses.



Jackson Lake provides storage for recreation, irrigation, and incidental flood control. (BR)

Table 37 - Multiple-Purpose Reservoirs with Space Allocated for Flood Control, Subregion 4

Reservoir	Owner	In-Service Year for Flood Control	Stream	Drainage Area (Sq. Mi.)	Normal Total Usable Storage	Exclusive Fld. Cont. Storage (1,000 Acre-Feet)	Joint- Use Storage	Surcharge Storage
Jackson Lake	USBR	1957	Snake R.	824	847	0	200	Est. 5.0
Palisades	USBR	1955	Snake R.	5,208	1,201	0	1,201	16.0
Ririe	USCE	1/	Willow Cr.	620	97	10	87	0
Little Wood	Priv. & USBR	1959	Little Wood R.	229	30	0	28	3.3
Teton	USBR	1/	Teton		200	0	200	0
Total					2,375	10	1,716	

1/ Under construction in 1970.

Table 38 - Storage Projects Affording Normal Incidental Flood Storage, Subregion 4

Reservoir	Owner	Stream	Total Usable Storage 1,000 AF
Grassy Lake	USBR	Henry's Fork	15.2
Island Park	USBR	Henry's Fork	127.6
American Falls	USBR	Snake River	1,700
Minidoka	USBR	Snake River	107.2
Milner	Private	Snake River	2.5
Lower Salmon Falls	Private	Snake River	5.2
Magic	Private	Big Wood	191.5
Henry's Lake	Private	Henry's Fork	79.4
Grays Lake	BIA	Willow Creek	40
Blackfoot Marsh	BIA	Blackfoot R.	350.0
Portneuf	Private	Portneuf	23.7
Harmon	Private	West Camas	6.0
Lower Goose Creek	Private	Goose Creek	74.3
Wilson Lake	Private	North Side Canal	18.5
Murtaugh Lake	Private	Dry Creek	3.0
Mud Lake	Private	Camas Creek	60.0
MacKay	Private	Big Lost River	44.5
Cedar Creek	Private	Cedar Creek	26.0
Fish Creek	Private	E. Fk. Fish Cr.	14.4
Salmon Creek	Private	Salmon Falls Cr.	182.6
Twin Lakes	Private	McKinney Creek	31.2
Two Ocean	Private	Two Ocean Lake	5.0
Miscellaneous farm ponds & small reservoirs			50.5

Levees and Channels

The Federal government, in cooperation with local interests, has constructed improved-channel and levee projects at nine locations in Subregion 4 (figure 8, table 39). Five locations are on the Snake River, namely: Jackson Hole, Heise to Henrys Fork, Henrys Fork to Roberts, Shelley Area, and Blackfoot Area. These main river projects provided in the aggregate 71.2 miles of levees of which 30.9 miles are revetted. The Pocatello project on Portneuf River consists of a rectangular concrete channel through the city with revetted levee and channel reaches on both ends where development is less extensive. The projects on Blackfoot River and Lyons Creek (also known as Lyman Creek) consist of channel rectification and levees. The project on Little Wood River near Gooding diverts floodwaters out of the river and into permeable lava beds. In addition to the projects described at the specific locations, about 100 miles of channel improvement have been accomplished on minor tributaries by the cooperative efforts of the Federal government and local landowners.



Flood control channel at Pocatello, Idaho on the Portneuf River. (USCE)

Table 39 - Levee and Channel Projects, Subregion 4

Location	Stream	Length of Channel Improvement (Miles)	Length of Levee (Miles)	Length of Revetment (Miles)	Design Freq. (Years)
Jackson Hole	Snake R.	0.0	24.0	23.9	220
Heise-Henrys Fork	Snake R.	0.0	28.0	6.0	135
Henrys Fork-Roberts	Snake R.	0.0	18.0	6.9	100
Blackfoot Area	Snake R.	0.0	1.0	0.8	40
Shelley Area	Snake R.	0.0	0.2	0.2	55
Pocatello	Portneuf R.	6.2	9.5	9.5	110
Blackfoot R.	Blackfoot R.	5.4	8.2	0.1	80
Lyons Creek	Lyons Creek	0.8	0.7	0.3	100
Gooding Location	Little Wood R.	7.0	1.0	0.0	45
Minor tributary streams		100.0	80.0	83.0	1/

1/ Degrees of protection afforded by these works are unknown. Considered to be 10 years or less.

Watershed Protection

Watershed protection practices applied to croplands include conservation cropping systems on 1,372,000 acres, crop residue use on 862,000 acres, irrigation water management on 824,000 acres, and land shaping on 456,000 acres. More than 562,000 acres of cropland have been adequately treated. Forest land treatment measures to reduce sediment and overland flow include 9,500 acres of erosion control work, and 383 miles of road and trail restoration.

Rangeland practices of particular significance include revegetation for improved cover and soil stabilization and better control and distribution of livestock grazing use. Grass has been seeded on about 1.2 million acres, brush was controlled on some 973,000 acres, and excessive grazing use was reduced on some 5.9 million acres.

The soils of this subregion have an approximate water holding capacity of 11.54 million acre-feet, or an average of 6.10 inches over the entire watershed. With proper land treatment and suitable climatic conditions this storage would be useful in controlling or retarding runoff. Additional information on land treatment is included in Appendix VIII.

Flood Plain Regulation Program

The services available under the flood plain information program have been discussed with governmental planning agencies in the Pocatello and Idaho Falls areas. They have been provided available information on the flood plains of recent large floods, primarily the February 1962 flood, and basic hydrologic information on small tributary areas in the vicinity of Pocatello. Final flood plain information reports have been prepared for the main Portneuf River and small tributaries in the vicinity of Pocatello and for the Big Wood River at Ketchum. Flood hazard information on Federal building locations at several cities in the subregion and information on Federal property to be sold in Bannock County have been given to the General Services Administration. The Atomic Energy Commission has been provided flood information on its Arco site.

Flood Forecasting and Emergency Operations

Flood forecasts are issued by the National Weather Service's Boise River District Office for key stations on the larger streams in the subregion. Table 40 shows the key river locations and the flood stage and corresponding streamflow.

Table 40 - Flood Warning Forecast Points, Subregion 4

<u>Location</u>	<u>Stream</u>	<u>Flood Stage (ft.)</u>	<u>Flow (cfs)</u>
Wilson, Wyo	Snake R.	1/	6,000
Heise, Ida	Snake R.	7.2	20,000
Rexburg, Ida	Henry's Fork	7.8	4,500
Pocatello, Ida	Portneuf R.	6.2	700
Hailey, Ida	Big Wood R.	1/	2,000

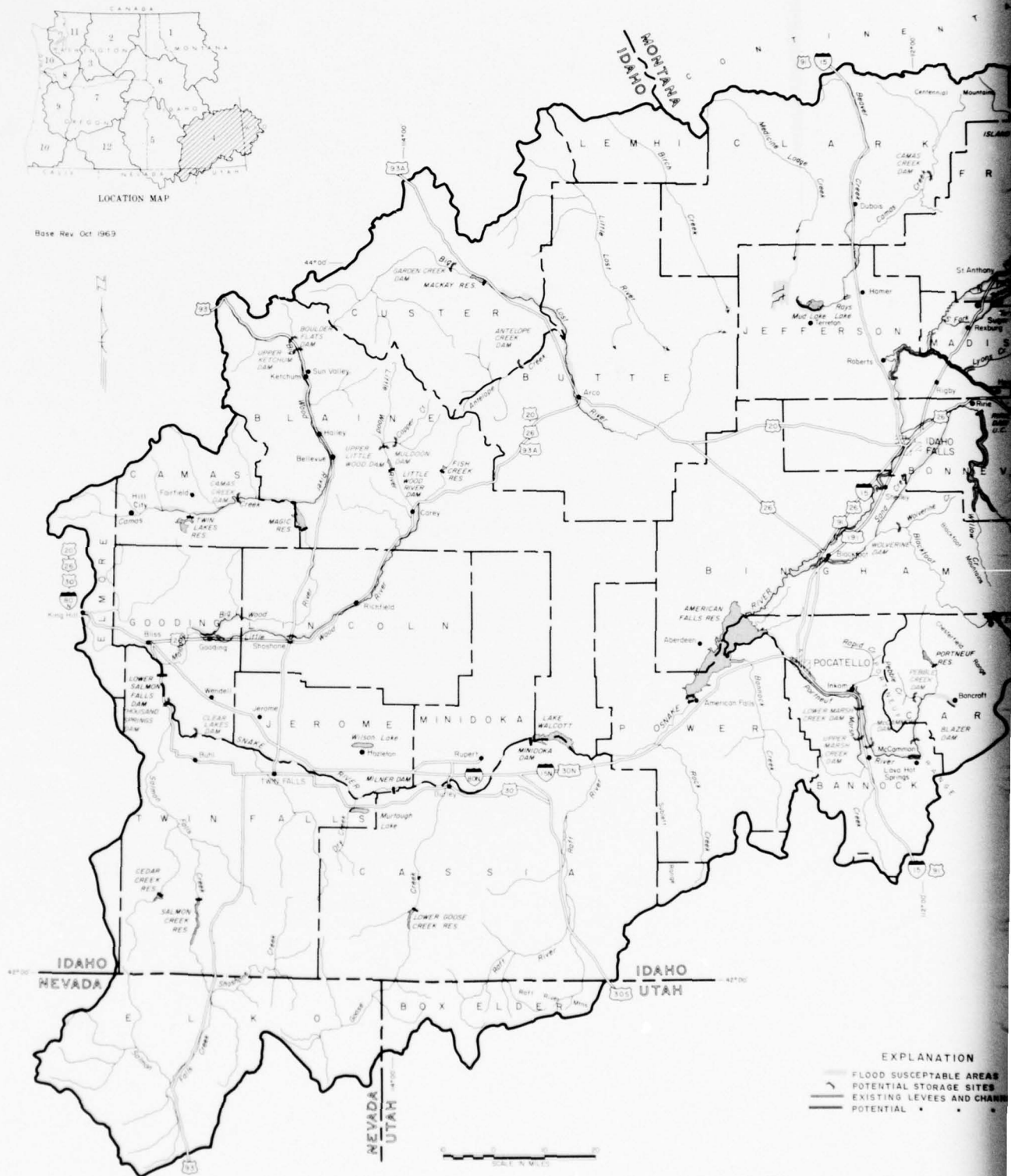
1/ Not available.

Flood warnings are issued when forecasts indicate that near bankfull stages are expected. Warning stage could be from 1 to 3 feet below actual flood stage. When the flood stage becomes critical, forecasts are issued at 24 hourly intervals or more frequently if weather conditions dictate. Forecasts are released until streams recede to below bankfull stages and all danger is passed. In addition to the forecast points listed in table 40, flood warnings are made for numerous smaller streams when flood emergencies arise.



LOCATION MAP

Base Rev Oct 1969



EXPLANATION

- FLOOD SUSCEPTIBLE AREAS
- POTENTIAL STORAGE SITES
- EXISTING LEVEES AND CHANNELS
- POTENTIAL

Flood emergency operations used in conjunction with flood forecasting have proven to be effective in reducing flood damages. Coordination among local law enforcement agencies, National Guard, Red Cross, Corps of Engineers, and state and local public officials including civil defense directors during periods of flooding provides an organization capable of implementing emergency plans. If possible, a central control center is established in the flood troubled area to facilitate coordination and communications and to direct operations. Emergency operations consist of diking and sandbagging to contain the expected flows, reinforcing sections of levees that are vulnerable to impinging high flows, and early removal of furniture, appliances, and other movable property. Areas in this subregion where emergency flood fighting and temporary evacuation are particularly effective in reducing substantial flood damages include the Jackson Hole and Heise-Roberts areas on the Snake River, the vicinity of Sugar City and Rexburg on the Teton River, the vicinity of Idaho Falls on Willow Creek, the vicinity of Blackfoot on the Blackfoot River, the Pocatello, Inkorn, Lava Hot Springs, and Bancroft areas in the Portneuf River Basin, and the vicinity of Gooding on the Little Wood River.

Accomplishments

Storage

Jackson Lake and Palisades Reservoirs regulate flood flows for the Snake River and contribute to downstream control of the lower Snake and Columbia Rivers, see table 82. These two reservoirs are operated in accordance with a plan prepared by the Bureau of Reclamation, Corps of Engineers, and irrigation interests for regulation of floods and conservation of water for irrigation and production of power. At Heise the unregulated 100-year flood of 68,000 cfs is reduced by the reservoirs to 30,000 cfs. American Falls Reservoir is operated in close coordination with Palisades and Jackson Lake. Such use often permits limiting Palisades flood releases to smaller amounts than would be otherwise permissible. Up to 600,000 acre-feet of space in this reservoir has been used in helping to control large floods, and it is planned that this amount will be used jointly for this purpose upon reconstruction of the facility. Flood flows in Little Wood River are reduced by storage in Little Wood Reservoir and similar control will be available for Teton River and Willow Creek on completion of Teton and Ririe Reservoirs, which are presently under construction. Such projects have a nominal effect on Snake and Columbia River floods. Irrigation diversions and reservoirs that have no allocated flood-control storage modify the magnitude of most natural flood peaks on many streams. However, in most areas this regulation is not always available when needed and the net effect in providing flood protection is considered to be only nominal. A notable

exception occurs on Henrys Fork where upstream irrigation reservoirs and large irrigation diversions reduce the magnitude of all spring and summer flood peaks. Approximately 700 acres of agricultural lands along Henrys Fork are thus protected from flooding and average annual damages in the basin are reduced by \$121,000.



Palisades Reservoir. (BR)

Storage projects reduce average annual damages along the Snake River in Subregion 4 by \$1,836,000 and along the larger tributaries by \$652,000 including the above \$121,000 along Henrys Fork. The areas flooded by a standard project flood are reduced by 71,200 acres along the main river and by 37,000 acres along the larger tributaries.

Levees and Channels

Levee projects along the main river and larger tributaries present average annual damages of \$832,000 and protect an estimated 20,950 acres.

Watershed Projects

Five comprehensive watershed projects, completed or under construction, protect 4,000 acres of agricultural lands and reduce average annual flood damages by \$28,000.

Flood Emergency Operations

Data are not available to furnish accurate and complete information on the accomplishments of flood emergency operations. However, it is considered that emergency operations reduce average annual damages by 10 to 20 percent. During the February 1962 floods, which were among the most severe experienced in Subregion 4, flood damages prevented by flood fight activities were estimated to be \$1,970,000 or 17 percent of the total potential damages from that flood.

Summary of Accomplishments

Data on acreages in the flood plains and damages without and with flood control projects are listed in table 41. Flood control effects of incidental storage and of land treatment measures and flood control projects on minor tributary streams have not been evaluated.

Table 41 - Project Accomplishments, Subregion 4

Stream	Station	Acres in Flood Plain 1/		Ave. Ann. Damages	
		w/o Proj.	w/Proj.	w/o Proj.	w/Proj.
Snake R.	Heise	89,550	6,500	2,314,000	179,700
Henrys Fork	Rexburg	9,300	8,500	162,900	21,000
Teton River	Sugar City	16,400	16,400	174,000	80,000
Lyons Cr.	Lower Lyons Cr.	11,700	6,000	12,500	3,600
Willow-Sand Cr.	Idaho Falls	110,000	75,000	480,000	116,500
Blackfoot River	Blackfoot	24,500	22,500 ^{2/}	95,000	3,700
Portneuf	Pocatello	8,300	6,900	229,000	121,200
Little Wood R.	Carey	4,400	3,200	565,000	188,000
5 Watershed Projects		4,000	0	31,000	3,000
Total		-	-	4,063,400	716,700

1/ Standard project flood.

2/ Reduction in flood plain due to improved channel vicinity of Blackfoot, Idaho.

Remaining Problems

Areas Flooded

Only a relatively small portion of the total area is susceptible to flooding. However, many of the flood-prone areas are

located in the more intensively used parts of the subregion. Generally, these areas lie in narrow strips along the streams and include rich farmlands, towns, and urban developments. Floods seldom cause loss of life but often result in extensive damage to lands and buildings, highways, railroads, irrigation facilities, and utilities. Table 42 gives data on areas in the flood plains and average annual damages for both the main stem and tributaries.

Table 42 - Areas Flooded, Subregion 4 ^{1/}

Stream	Minor Flooding			Major Floods			Average Annual Damages
	Flow (cfs)	Acreage in Flood Plain		Flow (cfs)	Acreage in Flood Plain		
		Urban	Rural		Urban	Rural	
Snake River							
Jackson Hole Area	6,000	0	50	10,000	0	150	\$ 37,950
Heise-Roberts Area	20,000	0	100	26,000	0	100	127,500
Blackfoot Area	20,000	0	50	26,000	0	100	13,850 2/
Shelley Area	20,000	0	0	26,000	0	0	400 2/
Salt River 3/							4,500
Henry's Fork	4,500	2	100	7,000	6	1,850	21,000
Teton	2,500	5	400	4,000	14	3,800	80,000
Willow-Sand Creeks	500	20	7,780	1,000	115	15,885	116,500
Blackfoot River	1,000	0	450	1,250	35	1,775	3,700
Portneuf River	1,000	7	345	2,000	30	975	121,200
Lyons Creek		0	0	0	0	0	3,600 2/
Mud Lake Basin	4/	400	4,700	4/	1,100	5,900	112,500
Big Lost River	1,000	25	1,975	2,600	100	13,900	132,400
Big Wood River	4,000	35	2,600	8,000	165	7,500	112,000
Little Wood River	1,100	400	170	2,000	900	1,104	188,000
Streambank Erosion	-	-	-	-	-	-	810,000
Tributary Areas					8,300	372,000	6,758,000
Total							\$8,643,100

^{1/} With 1970 flood control facilities and 1967 prices and economic development.

^{2/} Negligible flooding up to project design flood.

^{3/} Data not available for minor and major floods.

^{4/} Flows not given because flooding dependent more on flood volume.

Snake River Flooding in the lower Jackson Hole area results in damages to hay and pastureland, irrigation facilities, homesteads, and agricultural equipment. Flows below channel capacities in this area cause trouble at times by erosion of the banks and deterioration of the channel. Bank erosion and minor overbank flooding occur near the lower end of Swan Valley below Palisades Dam but damages are negligible. The reach from Heise to American Falls receives considerable flood protection from existing projects. Jackson Lake and Palisades Reservoirs reduce flood flows, and the existing levee systems provide further protection. At flows below the design capacity of the existing levees (table 39) damages comprise mainly crop losses and other damages on lands not protected by the levees, emergency expenditures, crop losses outside the flood plains caused by interruptions of irrigation water supplies, and other miscellaneous losses. At flows above the design capacity of the levees, irrigation works are badly disrupted and residences, public structures,

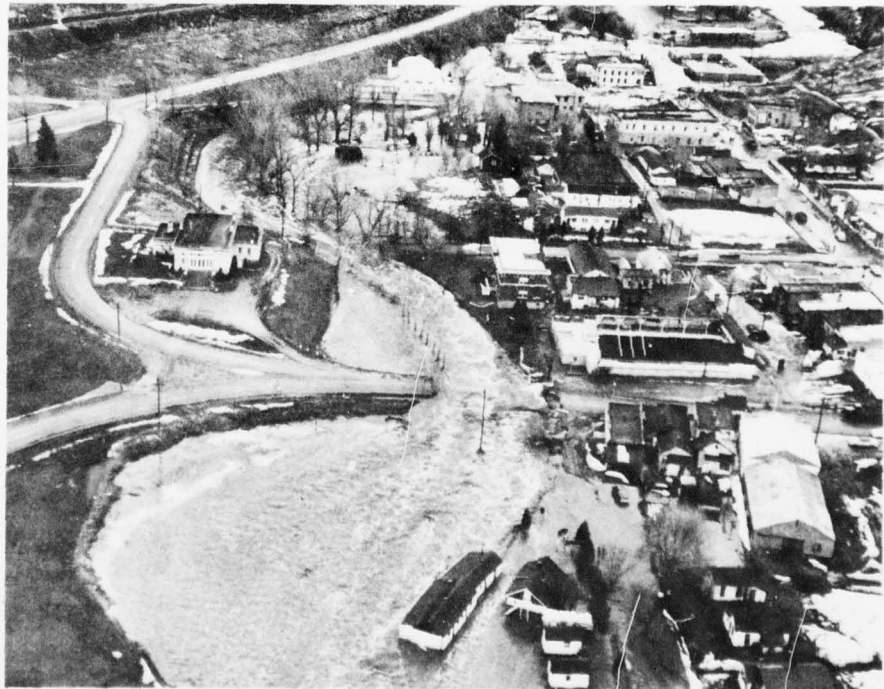
utilities, roads, and railroads are damaged. Because of the meandering nature of the river on its broad alluvial fan and the vulnerability of the existing levees, there is a possibility that the river could revert to old channels in the Heise-Roberts area.

Henrys Fork and Teton River The flood plain of Henrys Fork below the north distributary of Teton River encompasses a significant amount of cropland. Inundation in the area damages roads, bridges, irrigation works, farmsteads, and crop and pastureland. Flooding is of economic significance in the lower Teton Valley where high water tables also plague the areas subject to flooding. From the community of Teton to Rexburg and the Rexburg-St. Anthony Highway, cultivated hay and seeded pasturelands have been developed on both banks of the north and south branches of Teton River. Below the main highway, the development on the riverbanks becomes less extensive until, near Henrys Fork, relatively little land has been cleared for crop production because of frequent inundation. Inundation in the lower Teton Valley damages transportation facilities, irrigation works, farmsteads, crops, pasturelands, and urban properties in Rexburg and Sugar City.

Willow Creek-Sand Creek Basin The Willow Creek-Sand Creek flood plain extends downstream from the mouth of Willow Creek Canyon. Agricultural development in the flood plain consists of irrigated farms producing such crops as potatoes, sugar beets, alfalfa, and pasture. Also, major floods damage residential properties, utilities and transportation facilities consisting primarily of county roads, state highways, and farm lanes.

Blackfoot River The flood problem area in the Blackfoot River subbasin extends from the Blackfoot Diversion Dam, a few miles upstream from the town of Blackfoot, to the mouth of the river. The upper 7 miles of this reach has a combination residential-agricultural development, dominated by the city of Blackfoot. The flood plain includes a residential development with school, commercial, and transportation facilities. Agricultural lands in this reach and below the city include farmsteads and highly developed irrigated farms. Most of the damages in the basin are prevented by incidental storage in Blackfoot Marsh Reservoir and by local protection projects during the more frequent floods; however, damages from a flood of standard project magnitude would not be effectively reduced.

Portneuf River Basin Flooding occurs in reaches along the entire length of the Portneuf River downstream from Portneuf Reservoir, at the village of Bancroft in Gem Valley, and along Marsh Creek from the upper end of the valley to its confluence with the Portneuf River. Protection of the Pocatello area is afforded by a local flood control project, but upstream from Pocatello, floods damage agricultural lands as well as the towns of Lava Hot Springs and Inkom. Floodwaters from the Portneuf River cause damages to commercial and residential properties in the town of Lava Hot Springs. The flood plain is about 500 feet wide and high flow velocities result in severe losses. At Inkom the flood plain includes a residential area and a lime cement plant. Both Rapid Creek, which enters Portneuf River at Inkom, and the Portneuf River inflict damages which are primarily from inundation. The agricultural acreage in the flood plain from Portneuf Reservoir to the mouth of Marsh Creek is utilized for dairying operations, pasture, and production of hay and small grains. In this area the village of Bancroft is not on a defined stream but is in the path of intermittent flows that drain a 135-square mile area. The natural drain in the vicinity of the village has a very flat slope which causes temporary ponding and



Lava Hot Springs, Idaho, on the Portneuf River, 1962. (USCE)

resulting damages. In Marsh Creek Valley the majority of the land subject to inundation is devoted to improved hay and pastureland which is of prime importance to the cattle and dairy interests in the valley. Downstream from Pocatello, the Portneuf River flood plain consists of brush and pastureland, inundation of which would be of little consequence. However, a major flood would inflict damages to a commercial fish hatchery and possibly contaminate a source of water supply for the Union Pacific Railroad.

Lyons Creek The channel improvement project on Lyons Creek affords significant flood protection throughout the lower reach. Floods greater than the project design flood (100-year frequency) would inundate land devoted chiefly to irrigation farming and the production of potatoes, hay, small grains, and livestock.

Mud Lake Basin Camas and Beaver Creeks are sources of surface inflows to Mud Lake, which has no effective outlet other than irrigation canals, evaporation, and seepage. The principal flood problem in the Mud Lake subbasin is that, if the volume of inflow exceeds the available storage capacity of the lake, locally constructed dikes around the lake fail and permit flooding of farm areas south of the lake. The Mud Lake flood plain is principally in crops consisting of alfalfa, red clover, and sweet clover hay, and clover seed. Portions of residential and associated developments in the Terreton and Mud Lake communities, on the fringe of the flood plain, suffer minor damages under extreme flood conditions.

Big Lost River Most of the flood damages on the Big Lost River occur in the reach extending from Mackay Dam to below Arco. Agricultural development in this area is somewhat diversified and includes potatoes and grain along with the hay and pasture that are the staple crops.

Big and Little Wood Rivers The agricultural lands subject to flooding in the Big and Little Wood Valleys are used primarily for pasture and production of hay, wheat and other small grains, and some row crops. Floodwaters enter the towns of Ketchum, Hailey, and Belleview from Big Wood River, Shoshone from Little Wood River, and Gooding from both streams. Most of the flooding at Gooding is caused or augmented by the formation of ice gorges in the stream, but infrequent floods occur without the ice.

Other tributary streams Streams such as Pacific Creek, Buffalo Fork, Gros Ventre River, Greys River, Goose Creek, Salmon Falls Creek, Salt River, Medicine Lodge Creek, Birch Creek, Little Lost River, and other small tributary streams in the subregion experience flood damage. More than 8,200 acres of urban land, 283,000 acres of cropland, 4,000 acres of forest land, and 85,000

acres of rangeland are subject to flooding and average annual damages amount to \$6,758,000 of which \$975,000 are urban.

Streambank Erosion

Serious erosion occurs on an estimated 3,100 miles of streambank and the loss is estimated to average 10 feet for a total annual loss of 3,700 acres. Essentially all of the eroded material remains in the subregion. For study purposes, damages from streambank erosion are categorized into land loss, sedimentation, and other. Land loss represents the estimated value of land destroyed less any offsetting accretion, loss of use during the interim before accreted land can be brought back into production, and severance costs. Sedimentation losses include loss of reservoir and channel capacity, increased water treatment costs, deposition on flood plain lands, and adverse effects on aquatic life, recreation, etc. Generally, the listed damages from sedimentation are estimated as the cost of cleanup whether or not done. Other losses include such items as damage to bridges, culverts, and other fixed installations and deterioration of the environment.

Present average annual erosion damages are estimated to total \$810,000 broken down as follows:

	<u>Land Loss</u>	<u>Sedimentation</u>	<u>Other</u>
Urban	\$ 9,000	\$ 18,000	\$17,000
Rural	71,000	650,000	45,000
Total	\$80,000	\$668,000	\$62,000

PROJECTIONS AND NEEDS

Development in the subregion, because of the rugged terrain and the dependence on streamflows for the basic agricultural activity, will continue on the more flood susceptible valley bottoms. It therefore follows that floods will continue to significantly damage the economy even though the flood plains encompass only a small part of the total area.

Flood damages are expected to increase most rapidly in the Jackson Hole area on Snake River and along Willow-Sand Creeks and Portneuf, Big Wood and Little Wood Rivers. The potential for change in land use from agricultural to residential is significant in the Jackson Hole area and along Big Wood River at Ketchum, Idaho. The demand for homesites is becoming increasingly greater in these two highly popular recreation areas and the flood plains constitute a substantial portion of the land available for

subdivision. Urban developments subject to flooding on Willow-Sand Creeks and Portneuf and Little Wood Rivers are responsible for the expectation of significant increases in damages for these basins.

The present level of flood damages, \$8,643,000, is estimated to increase to \$11,367,000, \$13,859,000, and \$17,209,000 in the years 1980, 2000, and 2020, respectively. Table 43 lists current and projected levels of average annual damages on specific streams. The estimates of future damage levels are based on economic projections prepared for Appendix VI, "Economic Base Projections." The effects of presently (1970) existing flood control works are reflected in the projected damages, but effects of future measures, either structural or nonstructural, are not.

Table 43 - Current and Projected Flood Damages (1967 Price Levels),
Subregion 4

Stream & Area	Average Annual Flood Damage in Thousands of Dollars (1967 Price Levels)					
	With 1967 Economic Development			Under Projected Economic Development		
	Rural	Urban	Total	1980	2000	2020
Snake River						
Jackson Hole Area	36	1	37	55	86	147
Heise-Roberts Area	122	6	128	171	212	268
Blackfoot Area	14	0	14	17	25	33
Shelly Area	0+	0	0+	1	1	1
Salt River	4	0	4	6	7	9
Henrys Fork	21	0	21	28	33	40
Teton	69	11	80	108	139	180
Willow-Sand Creeks	79	37	116	173	283	510
Blackfoot River	4	0	4	5	6	8
Portneuf River	67	55	122	178	303	526
Lyons Creek	3	1	4	5	6	9
Mud Lake Basin	108	5	113	150	183	225
Big Lost River	114	18	132	179	229	300
Big Wood River	61	51	112	159	245	391
Little Wood River	54	134	188	277	472	814
Minor Tributaries	5,783	975	6,758	8,988	10,680	12,640
Streambank Erosion (all)	766	44	810	867	949	1,108
Total	7,305	1,338	8,643	11,367	13,859	17,209

The growth factors for agricultural damages were developed from crop yield projections for specific crops presently raised in the flood plains. Rural, nonagricultural damages were projected at the per-capita income growth factor for the subregion. For projecting urban, commercial, and industrial damages specific stream reaches were analyzed separately. The growth factor for these damages in the Jackson Hole, Idaho Falls, and Blackfoot areas was based on total personal income, which includes the element of population increase. In the Pocatello area, where past population trends for the lands not protected by the Portneuf channel project show an increase less than that for the subregion, a composite growth factor was used that was an average of the total personal income and per capita income factors. For Gooding and Rexburg, Idaho, which are the only other communities in Subregion 4 with populations greater than 2,500 that have lands in the flood plain, the per capita income growth factor was used

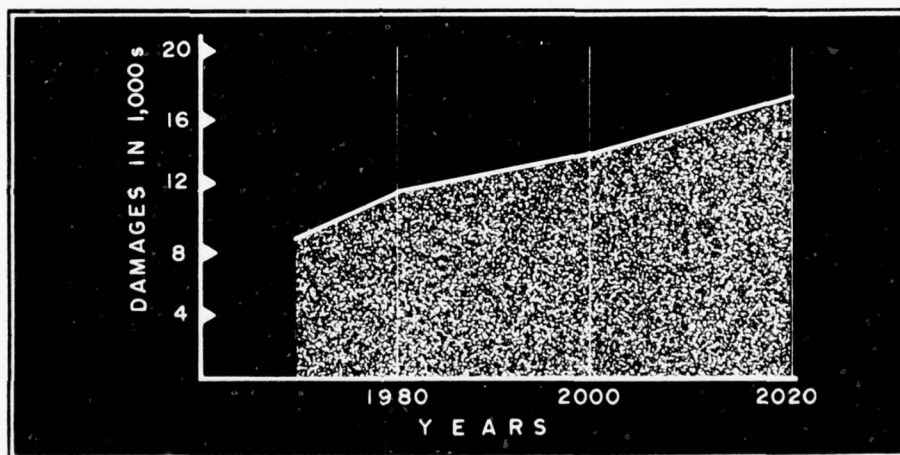


Figure 12. Projected Average Annual Flood Damages, Subregion 4.

for projecting damages because these areas have shown no significant increase in population in recent years. The communities with less than 2,500 population were included in the rural nonagricultural category. These economic growth factors were applied to average annual damages under present conditions of protection and economic development to obtain estimates of future damage levels.

The annual loss of land due to streambank erosion is not expected to change except as influenced by corrective measures. The value of land loss and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being primarily based on removal costs, remain constant. Future annual erosion damages, assuming no corrective measures, are projected to be \$867,000 in 1980, \$949,000 in 2000, and \$1,108,000 in 2020.

MEASURES REQUIRED TO SATISFY NEEDS

Measures that can be taken to help alleviate the flood damages include storage, channel and levee works, flood plain zoning, flood forecasts and combinations thereof. Storage capacities needed in specific areas to control floods of standard project flood magnitude to nondamaging stages are listed in table 44. These storage volumes were estimated without considering economic

Table 44 - Additional Storage Needed to Eliminate Flood Damages Caused by Major Streams, Subregion 4

Stream	Principal Flood Problem Area	Bankfull Capacity (cfs)	Upstream Storage Needed for Flood Control AF
Snake River	Lower Jackson Hole	6,000	600,000
Snake River	Heise to American Falls	20,000	1,500,000
Salt River	Afton to Freedom	1,000	200,000
Henrys Fork	Below N. Br. Teton	4,500	230,000
Teton River	Lower Teton Valley	2,500	130,000
Willow-Sand Crs.	Valley areas	500	25,000
Blackfoot River	Blackfoot to mouth	1,000	150,000 ^{1/}
Portneuf River	Portneuf Res. to mouth	700	200,000
Camas & Beaver Crs.	Areas around Mud Lake	400	38,000
Big Lost River	Mackay Dam to Arco	900	156,000
Big Wood River	Ketchum to Magic Res.	2,000	130,000
Camas Creek	Hill City to Magic Res.	2,000	50,000
Little Wood River	Little Wood Res. to Blaine County	800	35,000

^{1/} Would also increase the effectiveness of existing storage in Blackfoot Marsh Reservoir.

feasibility or availability of satisfactory storage sites although as shown in table 45, sites are available which would physically meet most of the storage needs.

Comprehensive water resource development demands that almost any reservoir project be multiple-use storage. Also, control of floods by storage alone to the extent that standard project flood is held to nondamaging stages is unlikely in most areas. However, lesser amounts of storage in combination with local protection projects and nonstructural measures may afford an adequate degree of protection along a stream.

Nonstructural measures comprising flood plain zoning and forecasting could help prevent an increase in future damages on most of the streams even though it is expected that most of the flood plain areas will continue to be utilized for agriculture. In the rural areas future farm buildings can be located to minimize flood damages, and roads, bridges, and utilities can be suitably flood proofed. With adequate warnings, livestock and mobile equipment could be moved to safe locations. In addition, as flood forecasting techniques become more reliable, better use can be made of conservation and joint-use storage for control of flooding.

Streambank protection is possible through either structural or vegetative means. The use of vegetative protective measures would necessarily be confined to the smaller streams and headwater areas. The average cost of vegetative protection per mile is estimated at \$8,000. Structural protective measures would be predominantly riprap, although in confined urban areas it may sometimes be more economical to protect the streambank by means of concrete retaining walls. It is estimated that riprap protection would cost \$40,000 per mile and concrete retaining walls would cost \$200,000 per mile.

Flood control measures that could reduce damages in specific problem areas are discussed below. Except as noted, the storage figures given are the amounts required together with existing storage, to control a provisional standard project flood to nondamaging stages. The storage could be joint-use but must be fully effective for flood control. Most of the data is taken from a previous study by the Corps of Engineers. (29)

Table 45 - Potential Flood Control Storage Sites, Subregion 41/

Basin and Stream	Damsite	Potential Storage (acre-feet)	Discussion
Pacific Creek	Pacific Cr.	464,000	Storage on Pacific Creek, Buffalo Fork, Gros Ventre River and Snake River above Jackson Hole could reduce damages in Jackson Hole area and downstream.
Buffalo Fork	Blackrock	505,000	
Snake River	Antelope Springs	325,000	
Gros Ventre	Cottonwood	300,000	Projects at Alpine & Lynn Crandall sites would reduce damages in Heise-Roberts reach & downstream. Clear Lakes & Thousand Springs could help reduce damages on Snake from damsites downstream to Brownlee Reservoir from large rare floods. Other possible uses for Snake River projects include recreation, power, and irrigation.
Snake River	Alpine	1,078,000	
Snake River	Lynn Crandall	1,620,000	
Snake River	Enlargement of American Falls Reservoir	Additional 1,400,000	
Snake River	Clear Lakes	1,070,000	
Snake River	Thousand Springs	595,000	Other possible uses for storage projects in Salt River Basin include irrigation & recreation.
Salt River	Star Valley	98,000	
Salt River	Salt R. No. 2	40,000	
Stump Cr. (trib. of Salt R.)	Lower Stump Creek	60,000	
Crow Cr. (trib. of Salt R.)	Upper Crow Cr.	40,000	
Crow Cr. (trib. of Salt R.)	Lower Crow Cr.	27,000	
Henrys Fork	Warm River	140,000	
Henrys Fork	Reconstruction of Ashton Dam	48,700	Storage on Henrys Fork would reduce damages on Henrys Fork & on Snake River from mouth of Henrys Fork to American Falls Reservoir. Other possible uses of reservoirs include power and recreation. Henrys Fork has been designated for inclusion in the National Wild and Scenic River System.
Teton River	Driggs	50,000	Storage on Teton River would reduce damages on Teton River, Henrys Fork, & Snake River from mouth of Henrys Fork to American Falls Res. Other possible uses of reservoirs include irrigation and recreation.
Teton River	Tetonia	590,000	
Blackfoot River	Wolverine	Not available	Could help control winter floods that emanate from drainages below Blackfoot Dam.
Portneuf River	McCammon	42,000	Construction cost of projects at McCammon & Blaser sites would be excessive because of extensive highway & railroad relocations involved. Portneuf River flows could be diverted into Lower Marsh Cr. Reservoir. Could provide recreation benefits as well.
Portneuf River	Blaser	45,000	
Pebble Creek (Trib. Portneuf R.)	Pebble Creek		
Marsh Creek (Trib. Portneuf R.)	Upper Marsh Cr.	21,000	
Marsh Creek (Trib. Portneuf R.)	Lower Marsh Cr.	70,000	Alternative to reinforcement of existing dikes around Mud Lake.
Camas Creek	Camas Creek	300,000	
Big Lost River	Garden Creek	180,000	Other possible uses for storage projects in Big Lost River Basin include irrigation & recreation.
Antelope Cr. (Trib. of Big Lost R.)	Antelope Creek	8,000	
Big Wood River	Boulder Flats	61,500	Storage on Big Wood River would reduce flood damages in the Ketchum-Hailey area. Little effect on flows below Magic Reservoir. Could provide irrigation and recreation benefits as well.
Big Wood River	Upper Ketchum	119,000	
Camas Creek (Trib. of Big Wood R.)	Camas Creek	50,000	Storage on Little Wood River would reduce flood damages in the reach from Little Wood River Reservoir to Blaine County Line. Could provide recreation & irrigation benefits as well.
Little Wood River	Upper Little Wood	10,000	
Copper Creek (Trib. of Little Wood R.)	Muldoon	10,000	
Farm ponds & reservoirs		88,300	Would be limited to incidental flood control effects.

1/ This information is furnished for possible use in plan formulation and includes the total storage capability at many sites. In most cases, the amount usable for flood control would be considerably less.

Major Streams

Jackson Hole Area About 600,000 acre-feet of additional storage including 200,000 on Gros Ventre River would be required upstream from Jackson Hole to control a provisional standard project flood to nondamaging stages, but a lesser amount would be effective against flooding. Downstream extension of the existing levees appears to be the most probable single-purpose flood control means for this area. Intermittent levees along a 10-mile reach of the stream would reduce damages by 60 percent and would significantly enhance the lands protected. This work would cost an estimated \$1,600,000. Levees would never completely eliminate flood damages because protection of all reaches is not feasible and the meandering nature of the stream would make the levees themselves subject to damages. Flood plain zoning could be a particularly useful tool in reducing damages in the Jackson Hole area. The entire valley is a popular resort area and demand is increasing for development of the flood plain lands for summer homesites. The possibility of minimizing future flood damages in this area, particularly the unprotected lower Jackson Hole reach, by flood plain zoning in combination with structural measures, needs to be given careful consideration.

Salt River Storage appears to be the only possible structural means of preventing any significant amount of the flood damages because damages are segmented and occur throughout the valley. Approximately 200,000 acre-feet of storage would be needed to control the provisional standard project flood. However, the total benefits available from flood control would not justify more than a fraction of the storage cost, and any flood control storage would have to be incidental to storage for irrigation and other purposes.

Heise to American Falls Reservoir Complete control of flood damage in the Heise to American Falls Reservoir reach of Snake River would require about 1,500,000 acre-feet of additional storage. This could include any storage provided above Jackson Hole, on Salt River, and 430,000 acre-feet on Henrys Fork. Additional slope protection is needed on the existing levees to prevent the possibility of avulsions. Irrigation intakes should be strengthened to assure a continuous supply of water during the irrigation season. There is a relatively small problem area about 6 miles northeast of the town of Blackfoot, Idaho, known as the Stephens Location. Studies have indicated that a left bank levee about 25,000 feet long costing about \$500,000 would provide protection from a flood flow of 33,000 cfs for this location, but the project would prevent less than 2 percent of the total damages in the Heise to American Falls reach. An increase in flood damages at Idaho Falls, Idaho, could be minimized by control of development in the flood plain. Rapid growth is exerting pressure for development on flood prone lands at that city.

Henrys Fork Flood problems in the Henrys Fork Basin after completion of the Teton Reservoir which is presently under construction will be found mainly along lower reaches of the Henrys Fork and the Teton River. An estimated additional 230,000 acre-feet of storage will be needed in the basin of which 130,000 acre-feet will be needed on the Teton River to control floods up to the provisional standard project magnitude in these lower reaches. Consideration has been given to protecting the lower 5 miles of the Henrys Fork, with a left bank levee that would cost about \$2,500,000. The Bureau of Reclamation is studying the possibility of diverting excess seasonal flows from the Henrys Fork above St. Anthony, Idaho, onto the Snake River plain at a location where this water would find its way into the regional ground water table. Diversion works with 1,500 cfs capacity would be equivalent to 111,000 acre-feet of flood control storage. Management of the flood plain at the towns of Teton, Sugar City, and Rexburg to prevent construction of damageable structures in areas subject to flooding could minimize the increase in future damages. Henrys Fork has been designated for inclusion in the National Wild and Scenic River System. (3)

Willow Creek-Sand Creek Basin The Ririe Dam and Reservoir is expected to provide a high degree of control on Willow Creek. However, substantial damages will remain on Sand Creek, which is the outfall for Willow Creek and acts primarily as an irrigation canal during normal discharge periods. Under natural conditions Sand Creek is fed from sidehill tributaries. Because Sand Creek is used as an irrigation canal, levee and channel works are not practical. Flood problems on Sand Creek can best be solved by control of Willow Creek flows at Critical times together with detention reservoirs on tributaries to Sand Creek to control sidehill runoff. About 25,000 acre-feet of additional storage on the tributaries would control floods up to provisional standard project flood magnitude.

Blackfoot River Detention reservoirs on tributaries to Sand Creek would reduce high flows on Sand Creek which enter the Blackfoot River near Firth, Idaho. If flows in Sand Creek were fully controlled, about 22,000 acre-feet of additional storage on the Blackfoot River would regulate a provisional standard project flood to nondamaging stages. An increase in the capacity of Blackfoot Marsh Reservoir up to a total of 451,000 acre-feet would be usable for flood control, but additional storage would be needed farther down the Blackfoot River to control winter floods that emanate from drainages below the dam. At the town of Blackfoot, Idaho, flood protection is afforded by channel and levee works; however, as the town expands there may be a tendency to build damageable structures outside of the protected area. This could be prevented by flood plain zoning.

Portneuf River Approximately 200,000 acre-feet of additional storage including 100,000 acre-feet above Lava Hot Springs and 60,000 acre-feet on Marsh Creek would be needed to control a flood of provisional standard project flood magnitude in the Portneuf Basin. Any project on the main river would entail extensive highway and railroad relocation costs. A project located in the lower reach of Marsh Creek, possibly with facilities to divert Portneuf flows into the Marsh Creek Reservoir, appears to have greater economic feasibility. Channel and levee projects at the towns of Bancroft, Lava Hot Springs, and Inkom would reduce total damages in Portneuf River Basin by about 50 percent. A project designed to protect Bancroft from floods up to 200-year exceedence frequency magnitude would cost about \$700,000. A channel and levee project at a cost of \$761,000 was recently authorized for the town of Lava Hot Springs. The project design flood has an exceedence frequency of once in 120 years. Enlarging the channel through the town of Inkom would cost an estimated \$70,000. Growth in future damages in the Portneuf River Basin can be minimized by proper flood plain regulation, particularly at the city of Pocatello. Although the city is protected to a high degree from floods on Portneuf River, development could spread into the flood plain area along the Portneuf River above and below the project and into the floodways of sidehill drainages. Other towns in the basin where nonstructural measures can be effective include Lava Hot Springs, Inkom, and Bancroft.

Mud Lake Basin The Corps of Engineers constructed a temporary safety way during a flood emergency in the spring of 1969 which diverts excess flows from Camas Creek onto nearby lava beds. Relatively complete control of flooding in the Mud Lake area could be effected by constructing a concrete diversion structure at the head of the emergency safety way and raising and strengthening the existing levees along the west and south shores of Mud Lake and along lower Camas Creek. These structural measures, costing about \$600,000, would reduce the basin's damages by over 90 percent.

Big Lost River Multiple-purpose storage development is considered the best means of controlling floods in the Big Lost River Basin. Levee and channel work would have limited results because the damages are inflicted by seepage waters inundating low-lying areas rather than overbank flows. An estimated 156,000 acre-feet of additional storage is needed in the basin to control large floods. Although the towns of Mackay and Arco have few buildings subject to flood damage, low-lying areas adjacent to the towns may be developed in the future if the flood plain is not managed to restrict this development.

Big and Little Wood Rivers Substantial flood control can be realized in the Ketchum-Hailey-Bellevue reach of Big Wood River by upstream storage. An estimated 130,000 acre-feet of additional flood control storage would control a flood of standard project magnitude in this reach. However, the effect of upstream storage would be markedly reduced in the Shoshone-Gooding area because of the large inflow to the Big Wood River below Ketchum. By the same token, floods on Little Wood River near Carey could be alleviated by upstream storage but little reduction would result on Little Wood in the Shoshone-Gooding reach. Thus, protection could only be provided for the Shoshone and Gooding area with a three-part project. Features of the project include a bypass channel around Shoshone for the Little Wood River floodwaters, an enlargement of the existing Gooding Safety Way to divert Little Wood River floods away from Gooding and into Big Wood River, and a channel enlargement on Big Wood River in the vicinity of Gooding sufficient to carry the flood flows of Big Wood River plus those diverted from Little Wood River. The bypass channel around Shoshone would cost more than \$655,000. The inter-related projects on Big and Little Wood Rivers near Gooding would cost \$1,100,000 or more. This three-part project would reduce total basin damages on Big and Little Wood Rivers by about 40 percent. A channel and levee project in the Hailey to Bellevue reach of Big Wood River would cost about \$300,000 and prevent about 10 percent of the average annual damages in the basin. Intermittent local flood protection works along the 20-mile reach of Little Wood River near Carey, Idaho, would cost approximately \$100,000 and prevent about 2 percent of the average annual damages in the basin. An important feature of this project would be a safety way on the East Fork of Little Wood River to divert floodwaters into lava beds where the water would enter the ground water reservoir. The Ketchum area is similar to the Jackson Hole area in that there is an increasing demand for building sites for summer homes. The popular Sun Valley recreation area is nearby and proper flood plain management is necessary to curtail building in the flood plain at Ketchum. Nonstructural programs also are applicable at the towns of Shoshone and Gooding.

Upland Areas

Combinations of improved management practices, land treatment measures, and water control structures will be necessary to satisfy future watershed needs for flood prevention. The most effective cropland practices that are still needed are 2,338,000 acres of crop residue use, 1,758,000 acres of irrigation water management, 1,628,000 acres of conservation cropping systems, and 450,000 acres of land shaping.

Forest land treatment measures required to reduce sediment and overland flow include 202,500 acres of erosion control treatment and 2,820 miles of road and trail restoration.



Sediment and debris deposited by flood waters. Proper land treatment would help control this type of damage. (SCS)

Rangeland practices required to reduce erosion and sediment and aid in reduction of flows include 2.2 million acres seeded to grass, 2.5 million acres of brush control and excessive grazing reduced on 3.7 million acres.

Structural measures needed on minor tributaries include 9,500 ponds and small reservoirs with a total capacity of 88,300 acre-feet, 100 miles of levees, 610 miles of stream channel improvements, 60 miles of stream channel stabilization, 5,420 miles of streambank protection, and nearly 2,000 miscellaneous other stream structures.

Comprehensive watershed treatment programs comprising both land treatment measures and flood control structures on minor tributaries will be needed by 176 watersheds. Twenty-five watersheds with 159,100 acres of flood plains should be treated by 1980; 33 areas with 109,400 acres of flood plains should be treated between 1980 and 2000; and the balance of the areas with

97,100 acres of flood plains after 2000. The works in these tributary areas are included in the above subregion totals.

Additional information on the land treatment measures is included in Appendix VIII.

Bank Erosion Approximately 15 percent of the seriously eroding streambank will require treatment prior to 2020. Along many of the smaller streams and in headwater areas, adequate protection can be achieved by use of vegetative measures at an average cost of \$8,000 per mile. Structural measures, predominantly riprap, will be required on the larger streams. It is estimated that riprap protection would cost \$40,000 per mile and that concrete retaining walls would cost \$200,000 per mile. Total costs of bank protective works in Subregion 4 are estimated to be \$5,000,000 through 2020.

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LOCATION MAP

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SUBREGION 5

CENTRAL SNAKE

GENERAL

Location and Extent

Subregion 5, the Central Snake, includes all the Snake River drainage system from King Hill, Idaho, (river mile 545) downstream to about 11 miles below Oxbow Dam (river mile 262). The area is elongated in a north-south direction having a width of more than 200 miles and a length of nearly 300 miles. The area is 36,825 square miles, of which 19,237 square miles are in southwestern Idaho, 13,955 square miles in southeastern Oregon, and 3,633 square miles in northwestern Nevada. The area is bounded by the Great Basin drainage system on the south; the remaining portion adjoins the Upper Snake, Lower Snake, Mid-Columbia, and Closed Basin Subregions.

Topography

Elevations range from about 2,000 feet at Oxbow Reservoir to nearly 11,000 feet in the Sawtooth Mountains. In the northern portion of the subregion the mountains rise abruptly to form ranges with several peaks in excess of 10,000 feet elevation. South of the Snake River, the mountain rise is more gradual and not as high. An important physical feature in the central and southeastern portions is the extensive plain along the Snake River from King Hill to Weiser, Idaho. This plain, which averages about 35 miles in width and varies in elevation between 2,100 and 4,000 feet, is the focus of most of the urban and agricultural development. The southwestern quarter, which includes the Owyhee River and South Fork Malheur River drainages, is a high, semi-arid plateau with elevations between 4,000 and 5,000 feet. Many of the streams in this area, together with much of the Snake River through the subregion and its tributaries from the south, are deeply incised in canyons. Extensive valleys occur in the lower reaches of the Weiser, Payette, and Malheur Rivers where the elevations are less than 3,000 feet. The Powder River Valley is narrow, but near Baker it expands to about 20 miles wide.

Climate

The climate is semi-arid, although local areas of higher elevation are moderately wet. The normal annual precipitation over most of the area is less than 15 inches. This amount is exceeded in the mountainous areas comprising the northeastern portion of the basin, and in small isolated areas along the southern and western borders. The winter months receive over one-half the total annual precipitation. Rainfall decreases in the spring, reaches a minimum during July and August, and then gradually increases during autumn. The proportion of annual precipitation occurring as snow varies from somewhat less than 30 percent at most valley stations below 3,000 feet, to about 50 percent at stations 5,000 feet or above. Summers are characteristically hot and dry, and winters are generally mild. Occasionally, however, polar continental airmasses spill over the Rocky Mountain barrier and cause subzero temperatures for short periods. Significant storms are usually the result of widespread meteorological conditions which produce storms throughout the Pacific Northwest. Such storms generally occur in the winter and less frequently in the spring or fall, and the heavy precipitation is generally confined to the more mountainous portions. Precipitation results from frontal activity, convergency, and orographic lifting or combination of these influences. Duration of storms varies from less than a day to more than a week, and the average duration is 2 to 4 days. These storms seldom produce precipitation exceeding a few tenths of an inch per hour or total amounts exceeding 2 inches per day. Summer thunderstorms occasionally produce high intensity precipitation for a few minutes over small areas.

Economic Development

About 268,170 people resided in the subregion in 1965. Approximately 53 percent were urban and 47 percent rural. The economy is based on agriculture. Raising livestock and crops such as potatoes and sugar beets predominate. Other strong contributors to the economy are industries based on mining and forestry resources, manufacturing, and service facilities. In 1960 there were about 94,350 people employed in Subregion 5. Employment in the commodity producing industries follows: agriculture, forestry and fisheries - 18,400; and manufacturing - 11,600. The principal cities are Boise, Nampa, and Caldwell, Idaho, which had 1960 populations of 34,481 ^{1/}, 18,013, and 12,230, respectively. Twelve other cities had populations in excess of 2,500 and 18 between 500 and 2,500. There were 16 towns with populations less than 500. About 72 percent of the land area is

^{1/} The 1967 official estimate for the city of Boise was 72,220.

range, 18 percent forest, 7 percent cropland, and the balance is other lands (see Appendix IV). About 27,000 square miles, 73 percent of the total area, is in public ownership of which 93.1 percent is Federal, 6.6 percent State, and 0.3 percent county and municipal. One railroad serves the core of the subregion; two airlines provide commercial service to Boise, and the road system consists of Interstate 80N, U. S. Highways 20, 26, and 95, and numerous State and county highways.

Streams

The Snake River enters the subregion flowing in a generally westerly direction, then gradually turns to leave the subregion flowing northerly after traversing 280 miles. It is dammed below the mouth of Bruneau River to form the C. J. Strike Reservoir and in the canyon reach below Weiser, is contained in the Brownlee, Oxbow, and Hells Canyon Reservoirs. Modified mean annual discharge of the Snake River at Oxbow Dam is 16,338 cfs; observed flows have ranged from a maximum of 76,800 cfs to a minimum of 441 cfs. The principal tributaries of the Snake River are the Boise, Payette, and Weiser Rivers from the northeast, and the Bruneau, Owyhee, Malheur, Burnt, and Powder Rivers from the south and west.

Table 46 - Streamflow Summary, Subregion 5

Stream	Total Drainage Area (Sq. Mi.)	Gaging Station	Drainage Area above Gaging Station (Sq. Mi.)	Mean Flow 1/ (cfs)	Momentary 2/ Flow, cfs	
					Max.	Min.
Bruneau River	3,310	Nr. Bruneau	2,630	342	6,500	25
Owyhee River	11,340	Owyhee Dam	11,160	252	22,900	0
Boise River	4,130	Nr. Boise	2,680	2,619	35,500	0
Malheur River	4,680	Little Valley	3,010	160	12,300	12
Payette River	3,270	Payette	3,240	2,707	30,900	180
Weiser River	1,660	Weiser	1,460	1,004	19,900	14
Burnt River	1,100	Hereford	309	82	2,200	0
Powder River	1,710	Mouth		512	5,500	18
SNAKE RIVER	-	Oxbow	73,150	16,338	76,800	441

1/ Regulated values for base period (1929-1958) 1970 conditions.

2/ Observed values for period of record.

Flood Characteristics

Floods result from either winter rain combined with snowmelt or from spring snowmelt. In any area, the principal factor determining which cause of flooding predominates is the mean elevation of the tributary basin. Winter floods generally occur on the tributaries to the south and west of Snake River, which have relatively low mean elevations, whereas spring floods

predominate on the tributaries to the northeast and east. In several tributary basins there is enough difference in elevation to cause spring floods to predominate in the upper reaches and winter floods in the lower valleys. Flash floods of cloudburst origin also occur, but such floods involve only small areas, principally in the foothills. Spring snowmelt floods last from several days to several weeks, and maximum flows do not greatly exceed the flows on the preceding or following days. Floods in this category usually do not produce major flood damages in this subregion because of upstream irrigation storage and diversions on the Snake River and on major tributaries, but they do contribute to floods on the lower Columbia River. In contrast, winter rain and snowmelt floods generally occur when the ground is frozen, and usually crest within a day following the maximum precipitation. The crest stages last only a matter of hours, and the streams recede to normal flow within a few days. Such floods cause extensive damages within the subregion. Ice jams are not normally a problem except on Powder, Weiser, and Burnt Rivers.

Table 47 shows pertinent data on bankfull and major flood stages and flows at key locations throughout the subregion.

Table 47 - Bankfull and Major Flood Stages, Subregion 5

Stream	Station	Bankfull			Major Flood		
		Stage (ft.)	Q (cfs)	Freq. 1/ (yr.)	Stage (ft.)	Q (cfs)	Freq. 1/ (yr.)
Snake R.	Murphy	10.5	30,000	3	16.5	60,000	50
Snake R.	Weiser	10.3	57,000	4	12.4	70,000	11
Boise R.	Boise	6.3	5,000	1	7.2	6,400	7
Payette R.	Emmett	9.1	12,000	2	10.7	16,000	5
Weiser R.	Weiser	8.0	9,200	2	10.5	18,000	20
Malheur R.	Near Vale	3/	10,000	25	3/	20,000	200
Bully Cr.	Vale	6.5	3,000	7	8.5	6,000	70 2/
Powder R.	Baker	3/	525	1	3/	930	6

1/ Frequencies with existing control.

2/ Possibility of thunderstorm floods not included.

3/ Not available.

HISTORY OF FLOODING

Damages in Subregion 5 during recent floods are summarized in table 48.

Snake River and Minor Tributaries

Most of the Snake River within Subregion 5 is located in a canyon relatively free of a flood plain. However, major floods have inundated large areas of highly developed agricultural lands along the 65-mile reach between Homedale, and Weiser, Idaho. The largest known flood occurred in June 1894, when the estimated maximum discharges at King Hill and Weiser were 83,000 cfs and 125,000 cfs, respectively. High-water marks at Weiser indicate that the river reached a stage 15 to 16 feet above low water and flooded an area several miles wide. The second largest known flood at Weiser occurred in March 1910, with an estimated peak flow of 120,000 cfs. Discharges in excess of 70,000 cfs at Weiser, which result in overbank stages in Snake River Valley in the vicinity of and above Weiser, have been exceeded five times since 1894.

Table 48 - Flood Damage Survey Data, Subregion 5

Date	Stream Gage & Location	Area Flooded (Acres)	Peak Discharge (cfs)	Damages 1/ Prevented	Damages 1/ Prevented
Apr 52	Snake R; Weiser, Ida	8,900	84,500	\$ 272,300	\$ 611,000
Dec 64	Weiser, Ida	2/	72,400 3/	350,000	50,000
Jan 65	Weiser, Ida	2/	61,700	1,300,000	2/
Feb 62	Bruneau R; Bruneau, Ida	2/	3,200 4/	60,000	0
Apr 52	Owyhee R; Rome, Ore	1,300	27,800	232,000	110,500
Dec 64	Rome, Ore	2/	33,500	327,300	900,000
Jan 65	Rome, Ore	2/	19,600	40,000	150,000
May 48	Boise, R; Boise, Ida	2/	9,860	0	43,000
Dec 64	Twin Springs, Ida	2/	18,800	550,000	13,397,000
Jan 65	Cottonwood Cr.; Boise	2/	152 5/	101,000	230,000
Mar 52	Malheur R; Vale, Ore	13,900	12,000	228,600	338,000
Feb 57	Ontario, Ore	18,300	24,000	2,176,000	2,600,000
Feb 63	Vale, Ore	7,550	13,500	403,000	515,000
Dec 64	Vale, Ore	2/	5,000-6,000	232,300	2,128,000
Jan 65	Vale, Ore	2/	11,000	328,100	2,047,000
May 48	Payette R; Emmett, Ida	2/	15,300	0	20,000
Dec 55	Emmett, Ida	2,300	22,700	175,000	1,350,000
Dec 64	Emmett, Ida	8,000	32,700	720,600	3,110,000
Dec 55	Weiser R; Weiser, Ida	6,790	19,900	285,000	30,000
Feb 57	Weiser, Ida	3,300	19,000	100,000	20,000
Dec 64	Weiser, Ida	4,000	17,200	384,100	2/
May 48	Powder R; Mouth	2/	5,320	76,000	0
Feb 57	Mouth	620	3,640 3/	210,000	2/
Feb 63	Mouth	9,370	2/ 3/	136,900	0
Dec 64	Mouth	10,000	1,120 3/	320,000	2/
Jan 65	Mouth	22,000	3,470	727,400	2/

1/ Values shown are basin-wide, and are based on development and price levels at time of flood.

2/ Not available.

3/ Augmented by ice jams.

4/ Most damages occurred on unregulated tributaries.

5/ Stream channel filled with sand causing overflow.

The largest recent flood at Weiser occurred in April 1952. (26) The recorded maximum flow was 84,500 cfs, but it is estimated that the unregulated peak would have been about 105,000 cfs. Flood damages amounted to \$272,300, but reservoirs, flood control structures, and irrigation diversions prevented damages of \$611,000. Flood damages were principally crop loss, soil erosion, and damages to farm improvements, buildings, and roads. Upstream irrigation reservoirs and diversions considerably reduce peak discharges, and have kept many other potential floods within banks.

The December 1964 and January 1965 floods caused serious damages on several smaller Snake River tributaries. (27) The January 1965 flood damages were much higher because several small southbank tributaries experienced locally heavy runoff and serious flooding from intense rains in the headwaters. The more serious flooding was on Castle, Catherine, Reynolds, Sinkers, and Succor Creeks.

Bruneau River Basin

Only one serious flood has occurred on the Bruneau River in recorded history. In March 1910, a flow of 6,500 cfs near Bruneau caused widespread flooding. Three minor floods have been recorded since then, with the greatest damages resulting in February and March 1962. (21) The peak of that flood was 3,200 cfs near Bruneau, and damages to bridges, roads, and reservoirs, together with bank erosion, amounted to \$60,000. Reports indicated that most of the damages were caused by ice which floated up during the February flood and formed jams when flows rose again in March. Most damages occurred on the West Fork in Elko County, Nevada.

Owyhee River Basin

The Owyhee River has a history of flooding dating back to 1904, but it was not until 1952 that a flood of serious proportions occurred. In April 1952, a peak flow of 27,800 cfs was recorded near Rome, Oregon, 89 miles above Owyhee Dam. (26) Owyhee Reservoir was nearly full when the flood started, so made only a small reduction in flow, and the peak discharge below the dam was 22,900 cfs. Flood damages to croplands, agricultural improvements, farm buildings, and roads in the reach from the dam to mouth amounted to \$232,000. Crop losses were nearly one-half of the total damages. No estimates of damages in the basin above the reservoir were recorded.

The December 1964 runoff was unprecedented in many areas of the upper basin, and the peak discharge of 33,500 cfs at the Rome gage was the largest flow ever recorded. (23) The peak discharge on Jordan Creek above Jordan Valley was 7,530 cfs, 132 percent higher than the previous recorded maximum. Less severe flooding followed in January 1965. Owyhee Reservoir had sufficient capacity to store the entire December 1964 flood inflow and most of the January 1965 inflow. The estimated damages prevented by this storage were \$1,050,000 on the lower Owyhee River and the Snake River downstream to Brownlee Reservoir. Damages, which were mostly agricultural, amounted to \$367,300 in the basin above the reservoir.

Boise River Basin

Major floods on the Boise River occurred in June 1896 and April 1897, with peak flows of 35,500 cfs and 29,900 cfs near Boise. Nine flood flows have been recorded since 1895; however, the magnitude of recent floods have been diminished by upstream irrigation and flood control reservoirs. Incidental regulation of Boise River floods was effected by Arrowrock Reservoir from 1915 to the mid 1950's. The construction of Anderson Ranch Dam (1950) and Lucky Peak Dam (1955) for operation in conjunction with Arrowrock Reservoir, provided sufficient flood control storage to eliminate flooding by Boise River in the lower valley by the more frequent floods.

Potentially, the flood of December 1964 would have been the most devastating in the history of the Boise River Basin. (23) The natural peak flow of Boise River at Lucky Peak Dam would have been approximately 44,000 cfs, 24 percent greater than the previous maximum in 1896. Near Twin Springs, upstream from Arrowrock Reservoir, the peak flow was 86 percent greater than the previous maximum in 55 years of record. However, the entire flood, except for conservation and water quality control releases, was stored in the reservoirs and no flooding occurred below Lucky Peak Dam. Damages to roads and bridges upstream from the reservoirs amounted to \$550,000 and 30 people were evacuated by air. Damages prevented by the three reservoirs during the December 1964-January 1965 floods were estimated to be \$13,397,000. Although the January 1965 flood on the Boise River was minor, some damages occurred in Boise from the tributary canyons that discharge into the river through the city. Damages and flood fight expenses for Cottonwood Creek amounted to \$101,000; the discharge was not recorded. Flooding on these tributaries usually results from summer cloudbursts.

Malheur River Basin

The Malheur River has a long history of flooding; however, flood damages have been relatively low because of the lack of development in the basin and more recently, because of regulation by irrigation reservoirs. Flows of 22,800 cfs occurred near Vale, Oregon, in 1894 and March 1910. Lesser floods have occurred at about 15-year intervals since then. The largest flood in the history of the basin occurred in February 1957. The peak flow at Vale during that flood was 20,800 cfs, but without reservoir regulation the natural peak would have been 28,000 cfs. (25) Bully Creek, tributary to the Malheur River at Vale, had a flood peak of 8,980 cfs at the same time. At the flood crest most of Vale was inundated to depths of 2 to 5 feet, and more than 18,000 acres of land were flooded to depths averaging 3 feet. Principal flood damages were to urban buildings and irrigated croplands, with lesser damages to roads, railroads, and bridges. Total basin-wide damages amounted to \$2,176,000, while storage reduced damages by \$2,600,000.

In December 1964 and January 1965, the basin was subjected to excessive runoffs, but because of excellent reservoir regulation, extensive damages occurred only along unregulated tributary streams and above the reservoirs. The estimated peak flow of the Malheur River at Vale was between 5,000 and 6,000 cfs in December, but without regulation it would have been about 22,600 cfs. While the January 1965 flood discharges were lower than those of December 1964 at most locations, the longer duration of high stages led to more damages. The combined damages for the two floods amounted to \$560,400, and were confined mostly to agricultural lands, bridges, and roads. Damages prevented by reservoirs and levees amounted to \$4,175,000. (23)

Payette River Basin

Although the usual cause of floods in the Payette River is snowmelt, warm winter rains that fell on the snowpack in December 1964 resulted in the highest flow ever recorded near Emmett, Idaho. (23) The peak discharge of 32,700 cfs was nearly 50 percent greater than any previously recorded. This happened in spite of the fact that Cascade and Deadwood Reservoirs stored all their inflows and reduced the natural flow peak at Emmett by 8,900 cfs. About one-half of the total \$720,600 in flood damages were to agricultural improvements and erosion of topsoil. Approximately 8,000 acres were flooded in Payette and Gem Counties between Emmett and Payette. Damages prevented by levees and reservoirs amounted to \$3,110,000. Six major flood flows in excess of 20,000 cfs have been recorded on the Payette near Emmett since 1921.

Weiser River Basin

The highest recorded discharge on Weiser River, 19,900 cfs at Weiser in December 1955, caused \$285,000 in damages. Incidental storage in Crane Creek and Lost Valley Reservoirs reduced the peak flow by an estimated 3,600 cfs and prevented \$30,000 in damages. It is estimated that 6,790 acres were flooded including major portions of the village of Midvale, Idaho. Principal damages were to croplands, buildings, roads, and bridges. (24)

In the December 1964 flood, damages were greater than during the 1955 flood although the peak discharge of 17,200 cfs at Weiser was less than in 1955. (23) Agricultural lands, irrigation headworks, bank stabilization, and low levees were particularly hard hit by the floodwaters. Approximately 4,000 acres were flooded, and damages amounted to \$384,100. Extensive flooding was experienced in the Little Weiser River Valley where floodwaters inundated the valley floor to depths of 2 and 3 feet over a large area. The peak discharge on the Little Weiser River was 25 percent greater than the previous maximum in 35 years of record. In the lower Weiser valley the floodwaters were one-fourth to one-half mile wide. The computed reduction in peak discharge by reservoir storage amounted to only 2,800 cfs; therefore, damages prevented were minor. The Weiser River has experienced major flooding seven times since 1904.

Powder River Basin

The maximum recorded flow of Powder River at the mouth was 5,500 cfs in May 1956. (24) Damages were not recorded.

During the December 1964 flood, ice barriers in the channel caused flooding of about 10,000 acres of hay and pasturelands between Baker and Haines. Estimated damages were \$320,000. Most of the inflow into Thief Valley Reservoir was stored so that only minor damages occurred in the Lower Powder Valley. In January 1965 about 22,000 acres of agricultural land were flooded between Baker and North Powder, and the Lower Powder Valley had considerable flooding of pasturelands. Estimated damages amounted to \$727,400 due primarily to erosion of cultivated lands, loss of hay and cattle feed, and flooded irrigation facilities. Thief Valley Reservoir prevented some damages but the lack of records on water stored and released precluded evaluation. It is estimated that flood fight activities prevented \$100,000 in damages during each of the floods. The peak discharge at the mouth was 3,470 in January 1965. (23) The natural channel capacity of Powder River at the mouth has been exceeded five times since 1932.

PRESENT STATUS

Existing Measures

Flood Control Storage

Eight multiple-purpose reservoirs in Subregion 5 are regulated for flood control on a forecast basis. Pertinent data for these reservoirs are listed in table 49. These projects have a total usable capacity of 2,344,400 acre-feet. About 2,270,400 acre-feet or 95 percent of the total active storage is jointly used for flood control and irrigation. One of the multiple-purpose projects - Phillips Lake on Powder River - has joint-use storage available for flood control and other purposes plus exclusive flood control storage. Uncontrolled flows over the spillway are further regulated by surcharge storage.

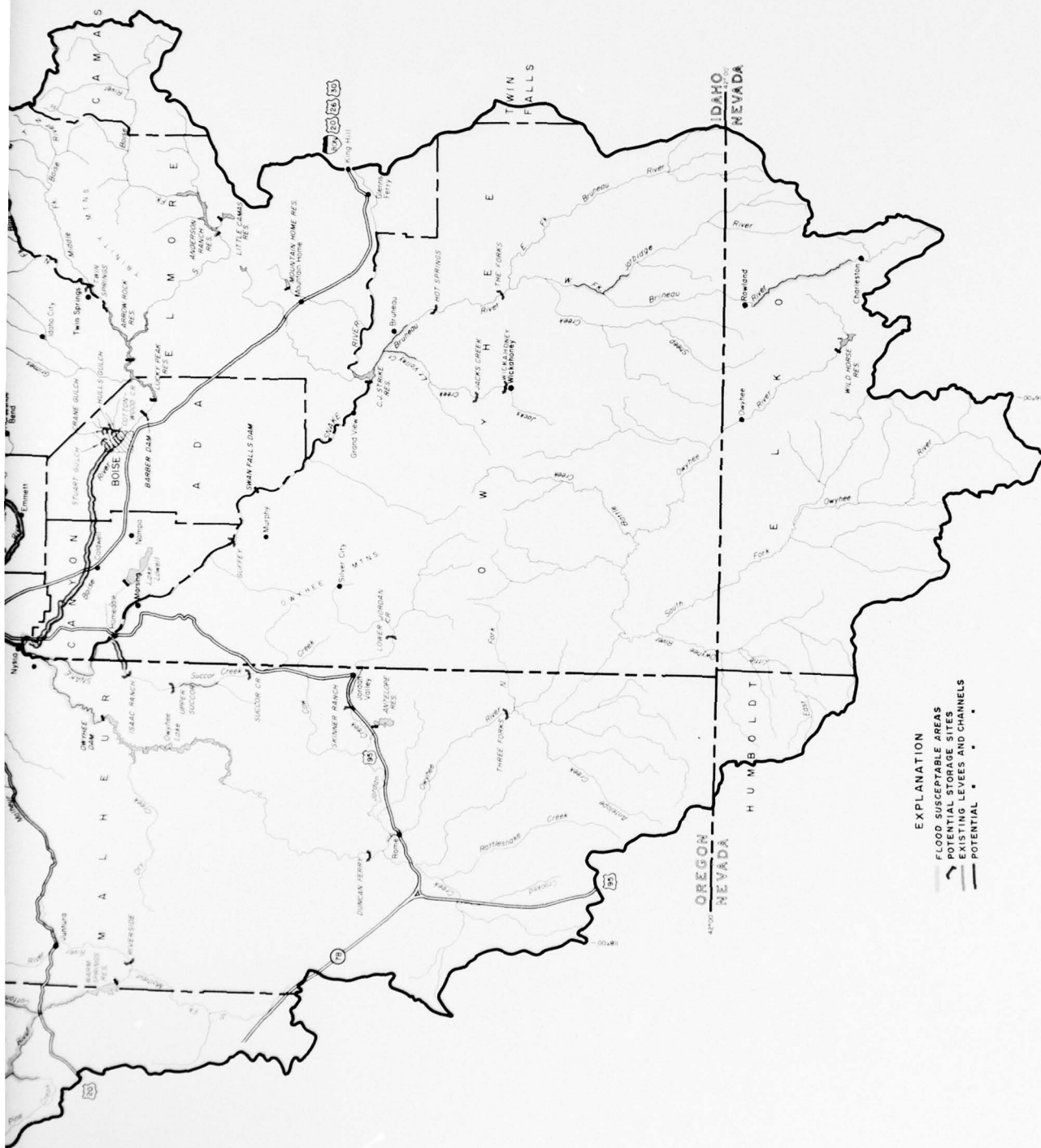
Table 49 - Multiple-Purpose Reservoirs with Space Allocated for Flood Control, Subregion 5

Reservoir	Owner	Inservice Year for Fld. Contr.	Stream	Drainage Area (Sq. Mi.)	Active Storage (1,000 AF)	Exclusive Fld. Contr. Storage (1,000 AF)	Joint Storage Avail. for Fld. Contr. (1,000 AF)	Surcharge Storage (1,000 AF)
Anderson Ranch	USBR	1950	Boise R.	980	423.2	0	423.2	9.5
Arrowrock	USBR	1917	Boise R.	2,210	286.6	0	286.6	11.6
Lucky Peak	USCE	1955	Boise R.	2,650	278.2	0	278.2	34.9
Warm Springs	USBR & Priv.	1926	Malheur R.	1,100	191.0	0	191.0	0.0
Brownlee	Idaho Pwr.	1958	Snake R.	72,590	980.2	0	980.2	0.0
Agency Valley	USBR	1935	Malheur R.	440	60.0	0	60.0	0.0
Bully Creek	USBR	1963	Malheur R.	547	30.2	0	30.0	7.2
Phillips Lake	USBR	1968	Powder R.	230	95.0	17.0	21.0	17.0
Total					2,344.4	17.0	2,270.4	80.2

1/ Expected to be under design-construction contingent upon appropriation of funds.
2/ Detention reservoirs.

Significant control of flooding has been provided by other storage reservoirs that are primarily operated for irrigation and power. These reservoirs are listed in table 50. They provide incidental flood regulation on the Snake River, on all principal tributaries except Bruneau River, and on several minor tributaries. In addition, there are about 4,900 farm ponds, and small reservoirs on minor tributary streams. The projects that provide incidental flood control have an aggregate storage capacity of 2,217,000 acre-feet and range in capacity from a few hundred acre-feet in the smaller farm ponds to 715,000 acre-feet in Owyhee Reservoir. Early in the season these projects generally have ample space available to store all flood flows, but in this semi-arid area they normally must be filled with the first available runoff in order to serve their primary functions.





COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY
**EXISTING & POTENTIAL
FLOOD CONTROL FACILITIES**
CENTRAL SNAKE SUBREGION 5

1970

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Table 50 - Storage Reservoirs that Afford Incidental
Flood Storage, Subregion 5

Reservoir	Owner	Stream	Usable Storage 1,000 AF
C. J. Strike	Private	Snake River	40.0
Swan Falls	Private	Snake River	6.9
Oxbow	Private	Snake River	5.0
Owyhee 1/	USBR	Owyhee River	715.0
Wild Horse	USBIA	Owyhee River	65.4
Antelope	Private	Jordan Cr. (Owyhee R.) 3/	45.4
Lake Lowell	USBR	Boise R. (off stream)	169.0
Hubbard	USBR	Boise R. 3/	7.5
Little Camas	Private	Little Camas Cr. (Boise R.)	22.3
Willow Creek No. 3	Private	Willow Cr. (Malheur R.)	20.4
Payette Lake	Private	N. Fk. Payette R.	27.7
Cascade 2/	USBR	N. Fk. Payette R.	653.2
Upper Payette	Private	Payette R.	8.0
Deadwood 2/	USBR	Deadwood R. (Payette R.)	161.9
Little Payette	Private	Lake Fk. (Payette R.)	16.9
Paddock Valley	Private	Little Willow Cr. (Payette R.)	32.0
C. Ben Ross	Private	Little Weiser 3/	7.8
Crane Creek 1/	Private	Crane Cr. (Weiser R.)	51.7
Mann Creek	USBR	Mann Cr. (Weiser R.)	11.0
Lost Valley	Private	Lost Cr. (Weiser R.)	10.0
Unity 1/	USBR	Burnt R.	25.2
Thief Valley	USBR	Powder R.	17.4
Farm ponds and stock reservoirs on small tributary streams			97.3
Total			2,217.0

- 1/ Reservoir has provided significant incidental flood regulation in past years.
 2/ Reservoir has provided significant flood regulation in recent years through informal operation for flood control.
 3/ Offstream reservoirs.

Levees and Channels

The locations of two major channel projects constructed by the Federal Government in cooperation with local interests are shown on figure 13, and data are listed in table 51. The channel and levee project on Malheur River is designed to protect Vale from flows up to 50-year frequency. The other project is located on Snake River opposite Weiser, Idaho, and is known as the Malheur Improvement District Project. This project consists of rock revetment designed to prevent an avulsion; the channel capacity of Snake River was not affected. The Federal agencies, with local assistance, have constructed many additional miles of levees and revetments as local protection works. These are primarily in the Boise, Payette, and Weiser Valleys. In addition, landowners with Federal technical assistance, have accomplished channel improvement, construction of levees, and bank protection on minor tributary streams. It is not practicable to identify each of the numerous locations where this work has been accomplished, but the total amount of work is shown in table 51.

Table 51 - Levee and Channel Projects, Subregion 5

Location	Stream	Length of Channel Improvement (Miles)	Length of Levees (Miles)	Length of Revetment (Miles)	Design Frequency (Years)
Vale, Oregon	Malheur R.	2.3	2.5	1.3	50
Malheur Improvement District	Snake R.	0.0	0.0	0.2	4 1/2
Minor and secondary tributary streams		190	45	1,040	2

1/ Channel capacity is not increased by the project.

2/ Degrees of protection afforded by these works vary. Considered to be less than 10 years.

Land Treatment Measures

The watershed protection practices applied to croplands in Subregion 5 which are most effective in reducing erosion and sedimentation and assisting in reduction of flood damages include conservation cropping systems on 508,000 acres, crop residue use on 311,000 acres, irrigation water management of 238,000 acres and land shaping on 363,000 acres. More than 519,000 acres have had combinations of practices which are considered adequate.

Forest land treatment measures to reduce sediment and tributary flood flow include 37,700 acres of erosion control work (consisting primarily of seeding of badly eroded areas and installation of gully plugs), 1,125 miles of road and trail restoration, and the construction of 105 other minor structures such as catch basins, drop inlets, and other flow retarding structures.

Rangeland practices of particular significance in reduction of erosion and sediment and aiding in reduction of flows include revegetation for improved cover and soil stabilization and better control of livestock grazing use. About 864,000 acres have been seeded to grass, and brush has been controlled on 929,000 acres. Excessive grazing use was reduced on 5.5 million acres.

It is estimated that the soils of Subregion 5 have a water holding capacity of at least 9,196,000 acre-feet or an average of 4.72 inches over the entire watershed. With proper land treatment and under ideal climatic conditions this storage would be useful in controlling or retarding runoff. Additional information on land treatment is included in Appendix VIII.

Flood Plain Regulation Program

The Corps of Engineers has prepared a flood plain information report for the city of Boise and Ada County. The report covers a 27-mile reach of Boise River from above the city to the Ada-Canyon County boundary. In addition, the flood plains in North Boise below four small intermittent streams - Cottonwood Creek, Hulls Gulch, Crane Gulch, and Stuart Gulch - are defined. Both the city and county are using the information in their comprehensive planning efforts. A flood plain information report has been prepared on the lower 9 miles of Payette River for Payette County. Gem County officials have requested a flood plain information report on Payette River. Flood hazard information at Federal building locations in several cities has been provided to the General Services Administration. The Veterans Administration was provided flood information on their buildings in Boise.

Flood Forecasting and Emergency Operations

Flood forecasts are issued by the Weather Bureau's Boise River District Office for key stations on the larger streams in the subregion. Table 52 shows the key river locations and the flood stage and corresponding streamflow.

Table 52 - Flood Warning Forecast Points, Subregion 5

<u>Location</u>	<u>Stream</u>	<u>Flood Stage (feet)</u>	<u>Flow (cfs)</u>
Boise, Idaho	Boise R.	6.3	5,000
Emmett, Idaho	Payette R.	9.1	12,000
Weiser, Idaho	Weiser R.	8.0	9,200
Vale, Oregon	Bully Cr.	6.5	3,000
Weiser, Idaho	Snake R.	10.3	57,000
Baker, Oregon	Powder R.	Not avail.	525

Flood warnings are issued when forecasts indicate that near bankfull stages are expected. Warning stage could be from 1 to 3 feet below actual flood stage. When flood stage is reached, forecasts are issued at 24-hour intervals or more frequently if weather conditions change radically. Forecasts are released until streams recede to below bankfull stages and all danger has passed. In addition to the forecast points listed in table 52 flood warnings are made for numerous smaller streams when flood emergencies arise. Close cooperation is maintained with State, county, and city authorities; Federal agencies; civil defense officials; private and public utilities; and news media.

Generally, flooding on the tributaries develop rapidly and there is little time to organize and implement sandbagging and levee construction operations. The effectiveness of flood emergency operations in this subregion has been primarily limited to debris removal at bridges and temporary evacuation of people, personal belongings, and livestock. However, flood fight activities involving the Corps of Engineers, National Guard, Civil Defense Directors and local volunteers, have prevented damages in several towns including Boise and Emmett, Idaho, and Vale, Oregon.

Accomplishments

Storage

Storage reservoirs and irrigation diversions in Subregion 4 are highly effective in reducing flood flows on Snake River in Subregion 5 and contribute to control of the lower Columbia River, table 82. The magnitude of the regulation of flood flows by Subregion 4 projects is reflected in the reduction in the standard project flood flow at Swan Falls, which is located upstream from flood control projects in Subregion 5. At Swan Falls the standard project flood is reduced from 130,000 cfs to 90,000 cfs by streamflow regulation. Brownlee Reservoir, the only storage project on Snake River in this subregion formally regulated for flood control assists in protection of downstream subregions. Storage projects on Boise, Payette, Malheur, and Powder Rivers regulate flood flows on their respective streams on a forecast basis, and contribute to the regulation of Snake and Columbia Rivers. Irrigation reservoirs in the Owyhee, Payette, Weiser, and Burnt River Basins have provided significant regulation of flood flows. Irrigation diversions on the Boise River are operated in a system with the reservoirs for flood control and substitute for about 400,000 acre-feet of storage.

Without existing flood control facilities, an estimated average annual damage of \$6,415,000 would occur on major and minor flood plain areas totaling more than 325,000 acres. Storage and watershed protection facilities reduce annual damages and afford a high degree of protection to about 152,000 acres, see table 53.

Levees and Channels

The two channel projects - one on Malheur River at Vale, and the other on the Oregon side of Snake River in vicinity of Weiser, Idaho - prevent average annual flood damage estimated at \$42,200 on about 270 acres of flood plain.

Flood Emergency Operations

A dearth of historical data makes an evaluation of the flood damages prevented by emergency operations difficult. Significant damages have been prevented by temporary evacuation of building contents, people, and livestock. Also, flood fight activities have reduced damages in urban areas. The most noteworthy flood fight in the subregion probably was the one the city of Boise conducted in January 1965 on Cottonwood Creek. Serious flooding and an estimated \$125,000 damages were prevented in town by sandbagging and channeling the creek through the streets to the Boise River.

Land Treatment Measures

Three comprehensive watershed projects have been constructed to protect more than 2,000 acres of agricultural land from flooding by small tributaries and overland flows. Average annual damages have been reduced on these lands by \$21,000. Effects of other land treatment measures and of other small reservoirs and flood control works have not been evaluated.

Summary of Flood Control Accomplishments

Data on flood flows, acreage in the flood plain, and damages for both "without" and "with" flood control projects are listed in table 53, which includes all major streams. Some streams are unregulated as reflected in the data.

Table 53 - Project Accomplishments, Subregion 5

Stream	Station	Acres in Flood Plain 1/		Average Annual Damages	
		w/o Proj.	w/Proj.	w/o Proj.	w/Proj.
Snake R.	Weiser	12,500+	12,500	\$ 127,800	\$ 95,100
Bruneau R. 2/	Bruneau	4,800	4,800	31,300	31,300
Succor Cr. 2/	Homedale	1,600	1,600	9,600	9,600
Jordan Cr. 2/	Jordan Valley	7,980	7,980	24,800	24,800
Owyhee R.	Owyhee Dam	2,000	2,000	97,900	65,400
Boise R.	Below Diversion Dam	76,000	38,700	2,048,500	99,700
Cottonwood Cr. 2/	Boise	481	481	33,600	33,600
Stuart Gulch 2/	Boise	500	500	35,100	35,100
Hulls Gulch 2/	Boise	215	215	5,800	5,800
Crane Gulch 2/	Boise	245	245	38,100	38,100
Malheur River	Vale	30,600	20,780	386,300	118,500
Payette River	Emmett	21,000	10,600	256,000	41,000
Weiser River	Weiser	7,920	7,920	122,500	93,800
Burnt River	Hereford	3,740	3,740	34,900	31,100
Powder River	Baker	39,700	36,600	68,000	18,600
3 Watersheds		2,000	-	25,000	4,000
Total		211,281+	148,661	\$3,345,200	\$745,500

1/ Standard project flood.

2/ No flood control projects on stream.

Remaining Flood Problems

Areas Flooded

Floods in Subregion 5 are more significant on the tributaries than on Snake River since most of the latter is located in a canyon relatively free of flood plain, while the lower reaches of the tributaries contain areas of highly developed lands that are subject to frequent flooding. Further, floods on the main river are regulated by upstream reservoirs and irrigation diversions both within and above the subregion. Flood problems exist on every important tributary stream in the subregion. Damages are principally agricultural and result from both inundation and bank erosion. The more highly improved areas are located on the alluvial lands along the lower reaches of the streams where the banks are composed of noncohesive materials that erode easily when subject to attack by floodwaters. Data on average annual damages and acreages in the flood plains are listed in table 54, and discussion of flood problems on specific streams follows.

Snake River From King Hill to Homedale, Idaho, Snake River flows in a canyon through an arid plateau, and the flood plain has little development. Downstream from Homedale, the valley widens, and the area that extends from there to below Weiser is highly developed. Flows that exceed bankfull capacity (57,000 cfs at Weiser) in this reach cause damage to rangeland, row crops, hay and irrigated pasture, farm buildings, irrigation structures, bridges, and highways. Major floods inundate additional structural properties and damage irrigation structures to the extent that water delivery to cropland outside the flood plain is interrupted. In addition, portions of the cities of Payette, Weiser, and Ontario, are flooded.

Bruneau River Floods damage irrigation structures and canals near Bruneau in the lower part of the basin and along Little Valley Creek. Pasture, hay, grain, and row croplands are inundated by large, infrequent floods. In the upper part of the basin - Elko County, Nevada, and along Jarbidge River - damages occur primarily to bridges and roads.

Succor Creek The flood plain in the Succor Creek basin is intermittent along the full length of the stream. Floods damage roads, bridges, irrigation works, and farmland. Croplands produce hay, grain, and some row crops while the major part of the farmlands are used for grazing.

Owyhee River The reach of Owyhee River downstream from Owyhee Dam sustains flood damages caused by high velocities

Table 54 - Areas Flooded, Subregion 5 1/

Stream	Flow (cfs)	Minor Flood Acreage in Flood Plain		Flow (cfs)	Major Flood Acreage in Flood Plain	
		Urban (Acres)	Rural (Acres)		Urban (Acres)	Rural (Acres)
Snake R.	57,000	30	1,970	70,000	100	9,900
Bruneau R.	3,500	15	2,545	5,000	50	3,650
Succor Cr.	800	5	255	1,500	25	735
Jordan Cr.	1,500	10	820	3,250	20	3,480
Owyhee R.	10,000	1	41	20,000	5	615
Boise R.	6,500	30	5,970	10,000	180	23,820
Cottonwood Creek	550	80	0	3,000	260	0
Stuart Gulch	1,000	86	0	2,000	219	0
Hulls Gulch	800	128	0	2,000	177	0
Crane Gulch	800	137	0	2,000	187	0
Malheur R.	2,900	10	890	5,600	40	3,220
Payette R.	12,000	0	0	16,000	100	2,225
Weiser R.	9,200	15	585	18,000	50	2,775
Burnt R.	180	4	131	880	17	1,713
Powder R.	525	8	1,192	930	25	15,975
Minor tributaries			-		2,200	123,000
Total		559	14,325		3,655	191,108

1/ With 1970 flood control facilities.

coupled with inundation. Floods deposit gravel and debris, scour river banks, and erode the land surface in this area of well-developed agricultural land. Also, irrigation systems, roads, and a railroad are damaged extensively. In the upper basin, flood damages occur in the vicinity of Jordan Valley. Damages along Jordan Creek are generally confined to native pasture and wild hay land and some alfalfa, hay and grain land. Jordan Creek also damages irrigation structures and roads.

Boise River Although storage projects have significantly reduced damages to residential and commercial properties along Boise River, agricultural properties, industrial areas, parks, a sewage disposal plant, and a golf course remain in the flood plain. A flood of standard project magnitude on Boise River would inundation portions of a Union Pacific Railroad branch line and Idaho State Highways 21 and 44.

Four normally dry tributaries just north of Boise - Cottonwood Creek, Hulls Gulch, Crane Gulch, and Stuart Gulch - drain the nearby mountain slope and are subject to occasional flash floods resulting from thunderstorms. Storage projects authorized in 1965 would almost eliminate flood damages on Cottonwood Creek and markedly reduce damages on Stuart Gulch. Land in the flood plains of all four tributaries is used mainly for residential purposes.



Flooding from Cottonwood Creek, 1959. (USCE)

Malheur River Reservoirs in Malheur River Basin afford significant regulation of flood flows and a channel improvement project provides 50-year protection for the town of Vale. However, overbank flooding and bank erosion still occurs along most tributary streams and along the lower Malheur River from the vicinity of Vale to the mouth. In the upper basin the damage areas are generally limited to native pastures and hay land, whereas, downstream from Vale the area is extensively developed for agriculture, and floods damage grain and row crops. Roads, railroads, and utilities are also damaged.

Payette River Flood damages in the Payette River Basin are confined primarily to the fertile lower Payette Valley that extends from Black Canyon Dam to the river mouth. In addition to inundation from overbank flows, damages result from a rise in the water table throughout much of the area. There are a number of locations where avulsions could occur and cause considerable damage and loss of land. Lands in the flood plain include irrigated domestic pasture and hay, row crops, and small grains. Major floods inundate urban properties in the towns of Emmett and Payette. U. S. Highways 30N and 95 and the main line of the Union Pacific Railroad cross the flood plain near Payette. State Highway 52 and a branch line of the Union Pacific Railroad parallel the river between Payette and Emmett.



Flooding near Payette, Idaho, December 1964. (USCE)

Weiser River Most of the flood damages in Weiser River Basin are concentrated in and near the towns of Council, Cambridge, Midvale, and Weiser. A standard project flood would inundate all of the community of Midvale and a portion of the town of Weiser. A few houses on the edge of Council are in the flood plain. Damages are limited to transportation facilities, utilities, and agricultural lands in the vicinity of Cambridge. Such damages also occur near the other communities. Lands subject to flooding near Council, Cambridge, and Midvale are used for irrigated pasture, alfalfa, and cereal grains. Floodwaters near Weiser inundate sugar beets, onions, and silage corn crops as well as irrigated pasture, alfalfa, and cereal grains. Several canyon reaches above and below Cambridge contain small acreages of agricultural land that are in the flood plain.

Burnt River Burnt River flows through a narrow canyon along most of its length and in the few areas of flat-bottomed valleys there is little development. The flood damages in this basin principally occur in the reach from Unity Reservoir to Durkee.

Powder River Most of the flood damages along the Powder River occur in a reach from Baker to Haines. This reach has a very flat gradient and, once flooded, drains very slowly. Hence, flood flows produce a saturated condition and prevent use of the land for weeks. Agricultural damages consist largely of loss of

use of pasture from prolonged inundation and silt deposition; damage to farm roads, bridges, fences, irrigation structures; and induced growth of noxious weeds and unpalatable grasses. In the town of Baker, commercial and residential properties and the city sewage treatment plant sustain varying degrees of flood damages. However, properties in Baker are not susceptible to prolonged inundation like the area downstream. Urban properties in Haines are not in the flood plain. Ice jams augment flood damages on Powder River.

Tributary Areas More than 2,200 acres of urban land, 79,000 acres of cropland, 7,000 acres of forest land, and 37,000 acres of range and pastureland in upland areas are subject to flooding by minor secondary tributaries.

Streambank Erosion Serious erosion is estimated to occur along 4,600 miles of streambank and the annual loss averages 10 feet for a total annual loss of 5,600 acres. Essentially all of the eroded material remains in the subregion. Present average annual erosion damages amount to \$1,100,000 of which \$975,000 is due to sedimentation, \$70,000 is due to land loss, and \$55,000 to other factors. More than 95 percent of the damages are rural.

PROJECTIONS AND NEEDS

General Economic Trends

Projections made for the Columbia-North Pacific Region indicate a population increase for Subregion 5 from 268,170 in 1965 to 328,700 in 1980, 430,400 in 2000, and 553,500 in 2020; an annual increase of about 1.3 percent with the greatest increase between 1980 and 2000. Total personal income is projected to increase at an average rate of 4.38 percent with a slightly higher rate prior to 1980. Most population increases are expected to occur in urban or suburban areas with rural populations generally decreasing.

Agricultural production is projected to increase, but employment in agriculture and food processing to decrease. Employment in other manufacturing and in auxiliary industries is projected to increase.

Land Use Trends in the Flood Plain

Urban growth in and around Boise is occurring on the flood plain of the Boise River and on the outwash from several normally-dry canyons that drain the hills north of the city. Further rapid growth on the Boise River flood plain is anticipated because the area receives some protection from the upriver reservoirs. A period of several years without flooding by the tributaries on the north side of the city would probably see residential developments spreading into those flood plains. Significant urban growth in flood plain areas is not anticipated at other cities in the sub-region.

Significant changes in cropping patterns are not projected nor is it anticipated that additional flood plain areas will be brought into agricultural production. However, flood damages are projected to increase in proportion to productivity.

Flood Damage Projections

The present level of flood damages in Subregion 5, of \$3,773,000 is estimated to increase to \$4,689,000, \$5,924,000, and \$7,708,000, in 1980, 2000, and 2020, respectively. Table 55



Development on flood plain below Crane Gulch, Boise, Idaho. (USCE)

lists current and projected levels of average annual damages on specific streams. The estimates of future damage levels are based on economic projections in Appendix VI, Economic Base and Projections. The effects of existing (1970) flood control works are reflected in the projected damages, but effects of future measures, either structural or nonstructural, are not.

The growth factors for rural damages were developed from crop yield projections for specific crops presently raised in the flood plains. For projecting urban damages, specific stream reaches were analyzed separately. The growth factor for these damages in the vicinity of Boise was based on total personal income, which includes the element of population increases. For the cities of Emmett, Payette, and Weiser, Idaho, and Baker and Ontario, Oregon, which have populations greater than 2,500 and lands in the flood plain, the per-capita income growth factor was used for projecting urban and related damages. The damages in communities with less than 2,500 population were included in the rural category. These economic growth factors were applied to average annual damages under present conditions of protection and economic development to obtain estimates of future damage levels.

Table 55 - Distribution of Current and Projected Flood Damages, Subregion 5

Stream Basin	Average Annual Flood Damage in \$1,000 1/					
	With 1967 Economic Development			Under Projected Economic Development		
	Rural	Urban	Total	1980	2000	2020
Snake River	91	4	95	124	157	195
Bruneau River	30	1	31	41	52	64
Succor Creek	9	1	10	13	16	20
Owyhee River	63	3	66	85	108	134
Jordan Creek	24	1	25	32	42	52
Boise River	66	34	100	138	208	321
Cottonwood Creek	-	34	34	62	142	320
Stuart Gulch	-	35	35	65	148	334
Hulls Gulch	-	6	6	11	24	55
Crane Gulch	-	38	38	69	159	360
Malheur River	79	39	118	161	232	336
Payette River	30	11	41	56	79	112
Weiser River	79	15	94	125	170	250
Burnt River	30	1	31	40	51	64
Powder River	17	1	18	24	32	41
Minor Tributaries and Upland Areas	1,738	193	1,931	2,491	3,090	3,688
Streambank Erosion, All Basins	1,045	55	1,100	1,152	1,224	1,362
Total	3,301	472	3,773	4,689	5,924	7,708

1/ 1967 price levels.

The annual loss of land from streambank erosion is not expected to change except as influenced by corrective measures. The value of land lost and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being based on the amount of work to remove and clean up, even though such work is usually not done at this time, will remain approximately constant. Future annual damages from sedimentation, due to loss of land, loss of land use, removal, and other factors, will amount to \$1,152,000 in 1980, \$1,224,000 in 2000, and \$1,362,000 in 2020.

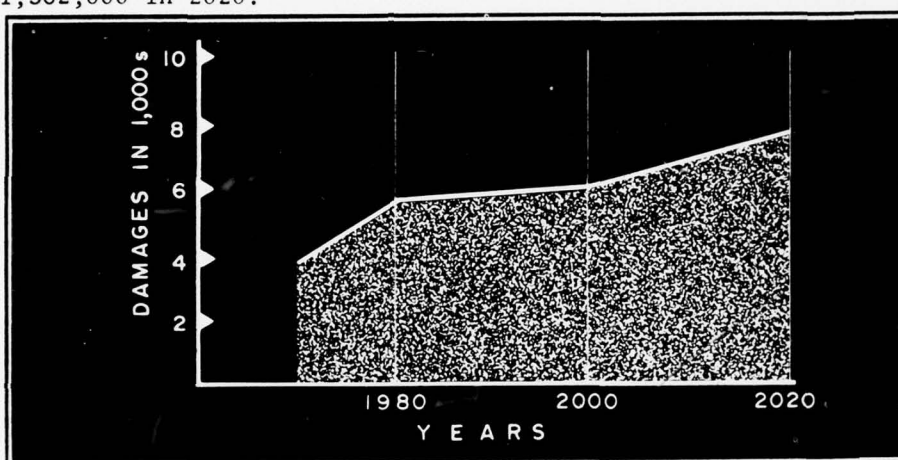


Figure 14. Projected Average Annual Flood Damages, Subregion 5.

MEASURES REQUIRED TO SATISFY NEEDS

Measures that can be taken to help minimize future flood damages include storage, channel and levee works, nonstructural measures, or combinations thereof. Storage capacities needed in specific areas to control floods of standard project flood magnitude to nondamaging stages are listed in table 56. Sites which could physically meet most of the storage needs are listed in table 57.

Nonstructural measures including flood plain zoning, flood forecasting, and emergency operations, and watershed treatment could help reduce future damages on most of the streams even though it is expected that most of the flood plain areas will continue to be utilized for agriculture. In rural areas future farm buildings can be located to minimize future damages, and roads, bridges, and utilities can be suitably flood proofed. With adequate warnings, livestock and mobile equipment could be moved to safe locations. Flood control measures that could reduce damages in specific problem areas are discussed below.

Table 56 - Additional Storage Needed to Eliminate Flood Damages Caused by Major Streams, Subregion 5

<u>Stream</u>	<u>Principal Flood Problem Area</u>	<u>Bankfull Capacity (cfs)</u>	<u>Upstream Storage 1/ Needed for Flood Control (ac.-ft.)</u>
Snake R.	Homedale to Weiser	57,000	3,000,000
Bruneau R.	Lower River and Little Valley Cr.	3,500	100,000
Succor Cr.	Lower stream reaches	800	20,000
Owyhee R.	Owyhee Dam to mouth	6,000	800,000
Boise R.	Boise to mouth	6,500	800,000
Cottonwood Cr.	At Boise	250	3,480 2/
Stuart Gulch	At Boise	50	1,400 2/
Hulls Gulch	At Boise	10	500 2/
Crane Gulch	At Boise	30	900 2/
Malheur R.	Vale to mouth	10,000	120,000 3/
Payette R.	Black Canyon to mouth	12,000	1,200,000
Weiser R.	Council to Weiser	9,200	150,000 4/
Burnt R.	Unity Reservoir to Huntington	200	40,000
Powder R.	Baker to mouth	525	40,000

1/ Except as noted, the storage needed is that required, together with existing storage available for flood control to control a provisional standard project flood to nondamaging stages. Storage needed does not consider availability of sites or economic feasibility. Storage may be joint use, but must be fully effective for flood control.

2/ Amounts shown include allowance for sediment storage because sediment is an appreciable part of the total.

3/ Existing reservoirs are operated in system for flood protection but do not provide full protection because of area uncontrolled and insufficient capacity for very rare floods. Additional capacity would reduce uncontrolled area.

4/ New storage would need to be located properly with perhaps 50,000 acre-feet or more on lower tributaries, including Crane Creek and Little Weiser River.

Major Streams

Snake River

About 2 to 3 million acre-feet of additional storage would control flooding in the highly developed area along Snake River from Homedale to below Weiser, Idaho. This storage could be satisfied by reservoirs on the main river and tributary streams in both Subregions 4 and 5. Adequate zoning of the flood plains at Payette and Weiser, Idaho, and Ontario, Oregon, could minimize the increase in flood damages in these towns.

Bruneau River

Flood damages in the upper Bruneau River basin could be minimized by flood proofing bridges, roads, and utilities.

Damages along the lower segment of Bruneau River and Little Valley Creek can best be controlled by storage. An estimated 100,000 acre-feet of additional storage would regulate rare floods.

Succor Creek

About 20,000 acre-feet of storage on Succor Creek for regulation of flood flows would afford adequate protection for the rural areas that are in the flood plains in this basin. Channel improvements and levees along the lower 5 miles of the stream, designed for a flood that has an unregulated frequency of 50 years, would cost an estimated \$175,000.

Owyhee River

Incidental flood regulation is provided by Antelope, Owyhee, and Wild Horse Reservoirs, which have a combined usable capacity of over 800,000 acre-feet. However, because the existing storage is not fully effective for flood control, it is estimated an additional 800,000 acre-feet would be needed to eliminate flood damages in the basin. Most of the damages occur in the reach below Owyhee Reservoir. Any storage above that reservoir would be effective in reducing damages along the critical lower reach. Control of floods in the basin's other problem area, vicinity of Jordan Valley, Oregon, would require upstream storage on Jordan Creek.

Boise River

Although reservoirs and irrigation diversions substantially control the Boise River, an additional 800,000 acre-feet would be needed to control a standard project flood. A multiple-purpose reservoir at the Twin Springs site between Arrowrock Reservoir and confluence of North and Middle Forks of Boise River would substantially increase the control of major floods. Bankfull capacity (5,000 cfs) would have a 50-year frequency. If the capacity of the Boise River channel downstream from Boise were increased to 10,000 cfs, flood damages would not occur until flows exceed about 100-year frequency. A series of channel improvements and levees in the reach from Boise to the river's mouth would cost about \$1,000,000. This work, in conjunction with flow regulation by Twin Springs Reservoir, would reduce damages along the Boise River by about 50 percent.

Side hill tributaries on the north side of the city of Boise cause extensive flood damage to residential properties. Cottonwood Creek would be almost fully controlled by the authorized Cottonwood Dam but the Stuart Gulch Dam would not control all of that drainage, see table 57. No flood control reservoirs have been authorized on Hulls Gulch or Crane Gulch. Constructing a detention dam at Hulls Gulch with the capacity to control floods up to standard project flood magnitude at the damsite would cost about \$625,000 and prevent 80 percent of the present average annual damages in Hulls Gulch. A detention dam on Crane Gulch designed to control the standard project flood at the damsite is estimated to cost \$675,000 and to prevent about 70 percent of the present damages. Rapid residential growth is occurring on the flood plain below Stuart and Crane Gulches and should be regulated. In the Hulls Gulch flood plain, undeveloped land is relatively scarce and growth there depends to a large extent on rehabilitation or replacement of existing structures; however, consideration of nonstructural measures are warranted there, also. Control of development in the Boise River flood plain at and near Boise has merit, as well. Formulation of a flood plain management program for the city of Boise should take cognizance of the possibility of unintentionally diverting development into the paths of other northside tributaries, such as Warm Springs Creek and Polecat and Pierce Gulches.

Malheur River

An additional 120,000 acre-feet of storage fully effective for flood control and located above Vale would afford protection along the lower Malheur River from the town of Vale to the mouth. In addition to protecting the lower reach of the stream, which is the principal problem area in the basin, this storage would reduce damages on any of the tributary streams on which it might be located. Bully Creek Reservoir reduces most flows on Bully Creek at Vale to bankfull capacity (3,000 cfs). Flows that exceed this magnitude can be expected to occur about once in 10 to 20 years. The unleveed reach along Bully Creek near Vale is presently agricultural; however, residential development could expand into this area because of the false sense of security that the reservoir creates. Other areas in the basin where future residential building might be expected to encroach on the flood plains are along lower Willow Creek, unleveed reaches of Malheur River in the vicinity of Vale, and lower Malheur River near Ontario. Local structural measures for these areas are not economically feasible at this time, thus, careful consideration should be given to restricting the construction of damageable structures.

Payette River

Garden Valley Dam on the South Fork Payette River could, in conjunction with the existing Deadwood and Cascade Reservoirs, regulate a standard project flood to bankfull capacity (12,000 cfs) at Emmett. An alternative project comprising channel improvement and levee works at intervals along the lower 38 miles of Payette River, designed for flows up to 22,000 cfs at Emmett, would cost about \$1,650,000. Nonstructural measures could minimize future damages at the towns of Emmett and Payette if the Garden Valley Reservoir is not constructed.

Weiser River

About 150,000 acre-feet of additional flood control storage including at least 50,000 acre-feet on lower tributaries would be necessary to control standard project floods on Weiser River. Although Goodrich Dam would have a capacity of 250,000 acre-feet, it would only reduce flood flows near Weiser by 50 percent. Inflow from below the damsite would prevent further control. Channel improvement and levee works costing about \$700,000 along the lower 5 miles of the river in the vicinity of Weiser would provide 30-year protection without Goodrich Reservoir and 100-year protection with. The combined project would reduce the total basin damages by about 70 percent. Channel improvement and levee works on Weiser River between river miles 6 and 13 and in the Cambridge and Midvale areas would cost almost \$3,000,000. Work of such magnitude is not economically justified under present development but may become so about the year 2000. Flood plain zoning would assist in controlling future development along the Weiser River and on the Snake River flood plains at Weiser.

Burnt River

Most of the flood damages on Burnt River occur throughout the 50-mile reach between Unity Reservoir and Durkee. Because the damages are widespread, storage would be the most effective structural measure that could be taken to reduce damages. Control of rare floods would require about 40,000 acre-feet of flood control storage located above the problem area together with the incidental flood regulation that is provided by Unity Reservoir.

Powder River

Storage would provide the most desirable means of stream control along the reach of Powder River from Baker to Haines,

Oregon. Present irrigation practices and drainage problems in that area preclude construction of levees and the extremely flat gradient would necessitate large channels for flood flows. About 40,000 acre-feet of flood control storage in addition to the storage provided by Phillips Lake would control a standard project flood. Any storage development in the basin would reduce flood flows in the lower Powder Valley which also experiences flood damages. Channel improvement at Baker may become feasible sometime in the future. Nonstructural measures would assist in minimizing future damages at Baker.

Minor and Secondary Tributary Streams

It is estimated that prior to 2020 the needed levee, channel, and bank protection improvements on minor and secondary tributary streams will comprise 1,250 miles of levees, 2,000 miles of stream channel improvement, 500 miles of stream channel stabilization, 6,850 miles of streambank protection, and 1,800 miscellaneous stream structures.

Land Treatment Measures

Cropland treatment measures needed to supplement existing practices for control of flood damages include 1,162,000 acres of irrigation water management, 1,920,000 acres of conservation cropping systems, 889,000 acres of crop residue use, and 337,000 acres of land shaping. Forest lands will need 257,000 acres of erosion control work and 1,530 miles of road and trail restoration. Needed rangeland practices include 2.4 million acres to be seeded to grass, 6.8 million acres of brush control, and improved control of grazing on 9.8 million acres.

Bank Erosion

Approximately 15 percent of the seriously eroding streambanks would require treatment prior to 2020. Along many of the smaller streams and in headwater areas, adequate protection can be achieved by use of vegetative measures at an average cost of \$8,000 per mile. Structural measures, predominantly riprap, would be required on the larger streams. It is estimated that riprap protection would cost \$40,000 per mile and that concrete retaining walls would cost \$200,000 per mile. Total costs of bank protective works in Subregion 5 are estimated to be \$7 million through 2020.

Comprehensive Watershed Treatment

Comprehensive watershed treatment programs comprising land treatment and small flood control structures should be applied to 95 watersheds which have a total of 53,500 acres subject to flood damages. The works on these watersheds are included with the land treatment measures and small flood control structures cited above. Additional information on these and other land treatment measures including a proposed schedule of application is included in Appendix VIII, Land Measures and Watershed Protection.

Table 57 - Potential Storage Sites, Subregion 51/

<u>Basin & Stream</u>	<u>Damsite</u>	<u>Potential Storage (ac.-ft.)</u>	
Bruneau River Basin			
Bruneau River	The Forks	100,000	Other possible uses for storages in Bruneau R. Basin include irrigation, power, F&W, & recreation. Bruneau R. is designated for potential addition to the national wild & scenic river system.
	Hot Springs	90,000	
Little Valley Creek	Jacks Creek	8,000	
	Wickahoney	8,000	
Succor Creek Basin			
Succor Creek	Succor Creek	7,200	Combination storage project and improved channel project along the lower reach of Succor Creek would provide high degree of flood protection. Other uses for storage include irrigation and recreation.
	Upper Succor Cr.	19,000	
	Isaac Ranch	20,000	
Owyhee River Basin			
Jordan Creek	Skinner Ranch	15,000	Damages on Jordan Creek are concentrated near the town of Jordan Valley.
	Jordan Creek	100,000	
Owyhee River	Duncan Ferry	635,000	Duncan Ferry Reservoir would effectively control floods up to 50-year exceedence frequency. Other uses of storage include irrigation, F&W, power, and recreation.
	Three Forks	1,000,000	
Boise River Basin			
Boise River	Twin Springs	490,000	Twin Springs Reservoir in combination with channel enlargement below Boise could provide protection from floods up to 100-year exceedence frequency.
Cottonwood Creek	Cottonwood Cr.	3,480	Detention dam.
Stuart Gulch	Stuart Gulch	1,400	Detention dam.
Hulls Gulch	Hulls Gulch	900	Detention dam.
Crane Gulch	Crane Gulch	500	Detention dam.
Malheur River Basin			
Malheur River	Riverside	250,000	Riverside Reservoir would drown out the existing Warm Springs Reservoir. Other smaller reservoir sites are available. Projects could provide irrigation and recreation benefits as well as flood control.
Willow Creek	Rehabilitate Willow Cr. No. 3	49,000	At present storage is limited to about 15,000 acre-feet due to structural weakness.
Payette River Basin			
Payette River	Garden Valley	1,940,000	About 1,600,000 a.f. of storage space in Garden Valley Reservoir and the existing Deadwood & Cascade Reservoir would regulate the standard project flood to bankfull (12,000 cfs) at Emmett. Other possible uses of storage at Garden Valley site include irrigation, power, and recreation.
Weiser River Basin			
Weiser River	Goodrich	250,000	Project at Goodrich Damsite would reduce rare floods to near bankfull at Cambridge & Midvale and afford about 50% reduction in floodflows near Weiser. Could provide irrigation and recreation benefits as well.
Burnt River Basin			
Burnt River	Dark Canyon	8,300	Other possible uses for storage projects in Burnt River Basin include irrigation & recreation.
	Hardman	11,000	
	Petticoat	6,600	
	Antlers	20,000	
Powder River Basin			
Powder River	Enlargement of Thief Valley Res.	Not avail.	Would contribute to flood control on lower Powder River.
Wolf Creek	Wolf Creek	17,800	Wolf Creek storage would contribute to flood control on Lower Powder River only slightly. Other possible uses for storage on Wolf Creek include irrigation and recreation.
Small tributaries		102,000	24,900 farm ponds and reservoirs.

1/ This information is furnished for possible use in plan formulation and includes the total storage capability at many sites. In most cases, the amount usable for flood control would be considerably less.



LOCATION MAP

20-000000

6

SUBREGION 6

LOWER SNAKE

GENERAL

Subregion 6, Lower Snake, includes all areas draining into the Snake River from river mile 262, about 11 miles below Oxbow Dam, to the mouth. The area is 35,081 square miles, of which 24,562 square miles are in central Idaho, 4,956 square miles in northeastern Oregon, and 5,563 square miles in southeastern Washington. This large area, which includes the entire drainage of both the Clearwater and Salmon Rivers, contains some of the most rugged topography in the region.

Topography

There are three distinct types of topography. The northwest section is characterized by wide expanses of fairly flat land lying at 1,000 to 2,000 feet in elevation and cut only by shallow canyons along the drainage courses. Joining the flat lands, to the east, is a foothill area that extends in elevation from 2,000 to 3,000 feet. This area is characterized by wide valleys with higher, bordering timbered hills. The remainder, about 80 percent of the subregion, is mountainous, extremely rugged, and generally covered by timber. Elevations range from about 300 feet at the mouth of Snake River to over 12,000 feet in Lost River Range of the Sawtooth Mountains. In the eastern and southeastern portions, many peaks in the Sawtooth, Lemhi, and Bitterroot Ranges, and the Yellowjacket and Salmon River Mountains rise to elevations from 10,000 to 12,000 feet. The southern and western rims are not as high, but peaks in the Seven Devils Range and the Blue and Wallowa Mountains range from 6,000 to nearly 10,000 feet.

Climate

This subregion has a considerable variance in climate and length of growing season, chiefly because of a wide range in elevation. Eastward moving Pacific maritime airmasses, though modified by intervening topographic barriers, have sufficient moisture content to produce considerable precipitation when lifted over the mountainous areas. The Clearwater River Basin, in particular, has relatively heavy precipitation because it is

so oriented that most Pacific airmasses are subjected to both vertical lifting and horizontal convergence. Other portions of the subregion, while having less efficient rain-producing features, receive reasonably large amounts of precipitation because of topographic variations. Normal annual precipitation ranges from about 7-1/2 inches near the mouth of the Snake River, to more than 60 inches in the headwaters of the Clearwater River. Average annual precipitation over the entire area is about 28 inches. The combination of winter precipitation and high elevations produces extensive snow fields which augment summer streamflows. Occasionally, cold continental air invades the area and produces brief periods of subzero temperatures at all elevations. The continental influence also results in periods of high temperature in the summer.

Storms affecting the area are of several types. The most severe and frequent storms occur during the winter and originate over the Pacific Ocean. Summer thunderstorms in the foothills produce localized high intensity precipitation for short periods. Snake River floods in this subregion generally result from snow-melt in mountainous regions.

Economic Development

The 1965 estimated population was 163,251; about 43 percent rural and 57 percent urban. The economy is mainly based on utilization of natural resources. Agricultural production includes wheat, peas, livestock, and other crops. Industries based on forestry and mining are also important as are service, manufacturing, and recreational activities. The number of people employed in 1960 was about 55,600. Those employed in commodity producing industries included: agriculture - 10,229; food processing - 1,040; and lumber and wood and paper production - 7,070. The principal cities are La Grande, Clarkston, Pullman, Lewiston, and Moscow. These cities had 1960 populations of 9,014, 6,209, 12,957, 12,691, and 11,183, respectively. Five other cities had populations in excess of 2,500 and 25 between 500 and 2,500. There were 35 towns with populations less than 500. About 65 percent of the land in the subregion is publicly owned. The approximate pattern of land use is:

	<u>Acres</u>	<u>Percent of Total Area</u>
Cropland	3,078,000	13.7
Range and forest area	18,579,000	83.1
Miscellaneous areas	714,000	3.2
Total	22,371,000	100.0

The subregion is served by U. S. Highways 30 (Interstate 80N), 95, 93, 12, and numerous state and county roads. Transportation facilities also include rail lines that serve most of the populated areas, one commercial airline, and commercial shallow-draft navigation on the Snake River below Lewiston.

Streams

The Snake River flows northward through the western half of Subregion 6, then turns and flows in a westerly direction to its confluence with the Columbia River - a total distance of about 250 miles. The river enters the subregion at an elevation of about 1,800 feet and falls about 1,500 feet to the mouth. There are five major dams on the Snake River: Hells Canyon, Lower Granite (under construction), Little Goose, Lower Monumental, and Ice Harbor. Mean annual flow on Snake River at Ice Harbor Dam is 45,984 cfs; observed flows have ranged from a maximum of 298,000 cfs to a minimum of 11,800 cfs. The principal tributaries of the Snake River in this subregion are the Imnaha River from the south; the Salmon River from the east; the Grande Ronde River from the southwest; Asotin Creek from the west; the Clearwater River from the east; the Tucannon River from the south; and the Palouse River from the north. Dworshak Dam, currently under construction, on the North Fork Clearwater, is the only major project on any tributary. Table 58 lists pertinent data on the principal tributaries. For additional information on streams and streamflow characteristics, see Appendix V.

Table 58 - Streamflow Summary, Subregion 6

Stream	Total Drainage Area (Sq. Mi.)	Location	Drainage Area (Sq. Mi.)	Mean Flow 1/ (cfs)	Momentary 2/ Flow	
					Max. (cfs)	Min. (cfs)
Imnaha	950	Imnaha	622	500	6,650	16
Salmon	14,100	White Bird	13,550	10,690	106,000	1,580
Grande Ronde	4,070	Rondowa	2,555	2,044	24,700	225
Asotin Cr.	320	Asotin	170	71	2,720	13
Clearwater	9,640	Spalding	9,570	14,573	177,000	500
Tucannon	510	Starbuck	431	164	7,980	15
Palouse	2,980	Hooper	2,500	543	33,500	0

1/ Regulated values for base period, 1970 conditions.

2/ Observed values for period of record

Flood Characteristics

Floods on the Snake River and the larger tributaries are generally the result of snowmelt in mountainous regions. Runoff from this source commences at lower elevations in March or April and annual peak flows occur between April and June. The timing of each peak flow is dependent upon the elevation of the

individual watershed, the temperature sequence during the melting season, and the distribution of the snowpack. During the high water season, which lasts from 60 to 90 days, streams may have several secondary peaks resulting from alternate periods of warm and cool temperatures. The Palouse River and some other streams draining areas below 5,000 feet in elevation occasionally have floods between the first of December and the last of April as the result of intense winter rains with or without snowmelt, and frequently occurring on a frozen ground condition. Floods of this type are of short duration; the streams rise rapidly and reach a crest within a day following the maximum precipitation. Crest stages last only a matter of hours, after which the streams recede to normal flow within a few days. During the summer, intense convective storms occur in the foothills over areas of less than 50 square miles and produce extremely high rates of runoff from the small drainage areas affected. Streams rise quickly, usually reach a crest within an hour following the maximum period of rainfall, and recede to normal low flow within a few hours. Floods of this type have a small runoff volume and exert little influence on the main stream or larger tributaries. The probability of occurrence of this type flood on any particular drainage basin is small. Table 59 shows pertinent data on bankfull and major flood stages and flows at key locations.

Table 59 - Bankfull and Major Flood Stages, Subregion 6

Stream	Station	Bankfull			Major Flood		
		Stage (ft.)	Q (cfs)	Freq. (yr.)	Stage (ft.)	Q (cfs)	Freq. (yr.)
Salmon R.	Salmon	6.5	10,000	3	7.6	14,000	16
Salmon R.	White Bird	29.7	80,000	5	1/	1/	1/
Grande Ronde R.	La Grande	5.6	4,000	3	7.6	7,000	18
Asotin Creek	Asotin	1/	4,000	30	1/	5,000	45
Clearwater R.	Spalding	18.0	110,000	35 2/	19.4	125,000	80 2/
Snake R.	Clarkston	38.1	325,000	1,000 2/	39.4	350,000	1,000 2/

1/ Not available.

2/ Frequencies as regulated by existing projects.

HISTORY OF FLOODING

Damages during recent floods are summarized in table 60. Description of significant floods by appropriate stream reaches follows.

Snake River

The largest known flood on the Snake River in Subregion 6 occurred in June 1894 when the estimated peak discharge at

Table 60 - Flood Damage Survey Data, Subregion 6

Date	Stream	Location	Area Flooded Acres	Peak Dis- charge cfs	Damages <u>1/</u> \$	Damages <u>1/</u> Prevented \$
May 48	Snake R.	Clarkston, Wn. <u>2/</u>	7,880	369,000	582,000	0
Dec 64		Clarkston, Wn.	807	247,000	1,887,000	0
Jan 65		Clarkston, Wn.	10	156,000	120,000	5,000
May 48	Imnaha R.	Imnaha, Ore.	<u>3/</u>	5,700	18,000	0
May 48	Salmon R.	White Bird, Ida.	18,000	103,000	546,000	0
Dec 55	Little Salmon R.	Riggins, Ida.	200	7,000 <u>4/</u>	685,000	0
May 56	Salmon R.	White Bird, Ida.	<u>3/</u>	106,000	250,000	80,000
Jun 57	Lemhi R.	Salmon, Ida.	700	2,600 <u>4/</u>	135,000	0
Jun 65	Salmon R.	White Bird, Ida.	240	96,600	81,000	132,000
May 48	Grande Ronde R.	Rondowa, Ore.	20,000	19,900	1,055,000	0
May 56		Troy, Ore.	20,000	16,900	270,000	0
Dec 64		La Grande, Ore. <u>5/</u>	Minor	5,120	70,000	0
Jan 65		La Grande, Ore. <u>6/</u>	22,330	14,100	2,660,000	400,000
Dec 64	Asotin Cr.	Near the mouth	807	6,500	909,600	
Jan 65			10	3,000	36,700	30,000
May 48	Clearwater R.	Spalding, Ida.	3,470	177,000	2,788,000	0
		Spalding, Ida.	<u>3/</u>	122,000	337,000	0
May 57		Spalding, Ida.	1,440	144,000	425,000	1,200,000
Jun 64		Spalding, Ida.	<u>3/</u>	141,000	1,664,000	441,000
Dec 64		Spalding, Ida.	114	122,000	1,268,000	171,000
Jan 65		Spalding, Ida. <u>6/</u>	185	81,800	1,925,000	404,000
Dec 64	Palouse R.	Colfax, Wn.	<u>3/</u>	11,000	472,000	185,000
Jan 65		Colfax, Wn.	<u>3/</u>	11,600	118,000	185,000
Dec 64	Tucannon R.	Starbuck, Wn.	1,746	7,980	639,000	0
Jan 65		Starbuck, Wn.	320	4,160	186,000	13,000

1/ Values shown are basin-wide and are based on development and price levels at the time of flood.

2/ One life lost.

3/ Not available.

4/ Estimated value.

5/ Only minor flooding in Grande Ronde Valley.

6/ Most damages occurred on tributaries.

Clarkston, Washington, was 409,000 cfs. The second largest flood occurred in May 1948 with a recorded peak flow of 369,000 cfs. (7) The latter flood, which contributed 35 percent of the flood flow on the Columbia River at The Dalles, originated largely in Subregion 6, with heavy contributions from the Salmon, Clearwater, and Grande Ronde Rivers. Since 1894, five floods have exceeded the bankfull capacity of the lower Snake River. The lower Snake River did not experience out-of-bank flows during the December 1964 flood; however, damages to construction activities

at Lower Monumental and Hells Canyon damsites amounted to \$1,887,000. (23)

Salmon River Basin

Most flood damages in the Salmon River Basin have occurred in the upper reaches near Challis and Shoup, Idaho, and along the Little Salmon and Lemhi Rivers. The lower Salmon River and most of the tributaries flow through primitive areas with little or no development. The maximum flood peaks at both Challis and Shoup were recorded in May 1956; basin-wide damages to agricultural lands, roads, bridges, and irrigation works amounted to \$250,000. (24) Flood flows have exceeded the natural channel capacity near Challis four times since 1943 and five times since 1921 near Shoup. Extensive flood damages were experienced on the Little Salmon River in December 1955, and on the Lemhi River near Salmon, Idaho, in June 1957. Runoff in the upper Salmon River basin was also heavy in June 1965, when the peak discharge on the main river at Salmon was 15,300 cfs, only slightly less than the maximum of a 57-year period. (23)

The largest known floods on the lower Salmon River with corresponding peak discharges near White Bird, Idaho, were June 1894, 120,000 cfs; May 1956, 106,000 cfs; and May 1948, 103,000 cfs. Those flows contributed heavily to the major Columbia and Snake River floods in 1894 and 1948. Since 1894, five major flood peaks in excess of 88,800 cfs have been experienced at White Bird.

Grande Ronde River

The record flood of 14,100 cfs at La Grande, Oregon, which occurred in January 1965, caused damages estimated at \$2,660,000. (23) Flood fight activities prevented an additional \$400,000 in damages. Much of the valley floor from La Grande to Elgin became a shallow lake, inundating barns, residences, railroads, and highways. Over 22,000 acres were flooded, including 300 acres in La Grande. It is believed that this flood was greater than any at La Grande in the past 100 years. The peak discharge for this flood at Troy, Oregon, on the lower Grande Ronde River, was 33,100 cfs. The largest flood of record at Troy occurred in December 1964 with a discharge of 42,200 cfs; however, only minor flooding occurred in the upper valley.

Asotin Creek

The largest known flood on Asotin Creek (6,500 cfs) occurred in December 1964. (23) The entire length of the stream was devastated by the flood; and damages to roads, agricultural land, and the town of Asotin amounted to over \$900,000. Based on historical accounts of high water and bridge capacity, floods of about 5,000 cfs magnitude have occurred three times since 1900.

Clearwater River Basin

The largest flood of record on the lower main Clearwater at Spalding was 177,000 cfs in May 1948. (7) The maximum flood on the North Fork was 100,000 cfs in December 1933, and on the upper main Clearwater at Kamiah it was 103,000 cfs in June 1964. (23) Major flood flows in excess of 140,000 cfs at Spalding have been recorded four times since 1933. Peak discharges in excess of 70,000 cfs have occurred at Kamiah ten times since 1913, and have been recorded six times since 1933. Several small tributaries have also flooded.

During the May 1948 flood, total damages amounted to \$2,787,000. (7) Water covered a large portion of the towns of Stites, Kooskia, and Orofino, and part of the city of Lewiston. Many sawmills were damaged and all of them lost logs. Highway and railroad bridges and roadbeds were undercut and washed out. Many small levees were damaged, and one life was lost. Less damaging floods in the Clearwater basin occurred in May 1956, May 1957, June 1964, December 1964, and January 1965. (23) Major flood damages were to developments along the principal tributaries and the main stem in the 1956 and the two 1964 floods, while the minor tributaries suffered the principal damages during the 1957 and 1965 floods. Considerable benefits from levees and flood fight activities have been achieved since the May 1956 flood.

Palouse River Basin

The most extensive flood damages in the Palouse River Basin have been to urban developments in Pullman and Colfax. The outstanding damages at Pullman were caused by the floods of March 1910 and February 1948. The most serious damages at Colfax resulted from the 1910 and December 1933 floods. (7) Other urban areas in the basin have not experienced significant damage except for infrequent periods of extreme runoff. Highway and railroad bridges on most of the streams were washed out or damaged during the 1910 flood, and extensive road and railroad damages have occurred in other major floods.

The largest flood on the South Fork at Colfax, Washington, occurred in March 1910, with an estimated peak discharge of 11,500 cfs. While not the largest on the main Palouse River above Colfax, the 1910 flood was the most devastating, basin-wide. Practically every portion of the basin situation on any stream course or at the junction of normally dry coulees was subject to overflow damage during the extreme runoff, and damages in Whitman County were over \$2,000,000. The highest discharges in the upper reaches of the main stream occurred in December 1933, with discharges of 13,000 cfs at Colfax and 10,000 cfs at Palouse. (7)



South Fork Palouse River at Pullman, Washington, March 1, 1910. (USCE)

The flooding of December 1964 produced damages in several small communities located on tributary streams. Damages amounting to \$472,000 resulted from flooding of residences, grain storage buildings, business buildings, and numerous small bridges. January 1965 flooding was less severe, and resulting damages to roads and bridges amounted to \$118,000. The partially completed channel project at Colfax prevented an estimated \$185,000 in damages during each flood. (23)

Tucannon River Basin

The largest known flood on the Tucannon River occurred in March 1910 when the estimated peak discharge at Starbuck, Washington, was 9,000 cfs and the entire town was reportedly flooded to a depth of 3 feet. (7) According to Starbuck residents, bankfull capacity

(4,000 cfs) had been exceeded 12 times during the period 1906 to 1965. The largest recorded flood was in December 1964 with a peak discharge of 7,980 cfs. Water flowed through the streets to a depth of 2 feet, and many homes were damaged. The flooded area was 42 miles long and averaged 270 feet in width. Damages, mostly to agricultural lands, roads, and bridges, amounted to \$639,000. The January 1965 crest was only 4,160 cfs but damages, plus flood fight activities, amounted to \$186,000. (23)

PRESENT STATUS

Existing Measures

With the many miles of free flowing rivers and little economic development, this subregion has fewer structural measures than most other parts of the region. The following discussion outlines both the structural and nonstructural measures employed to reduce flood damages.

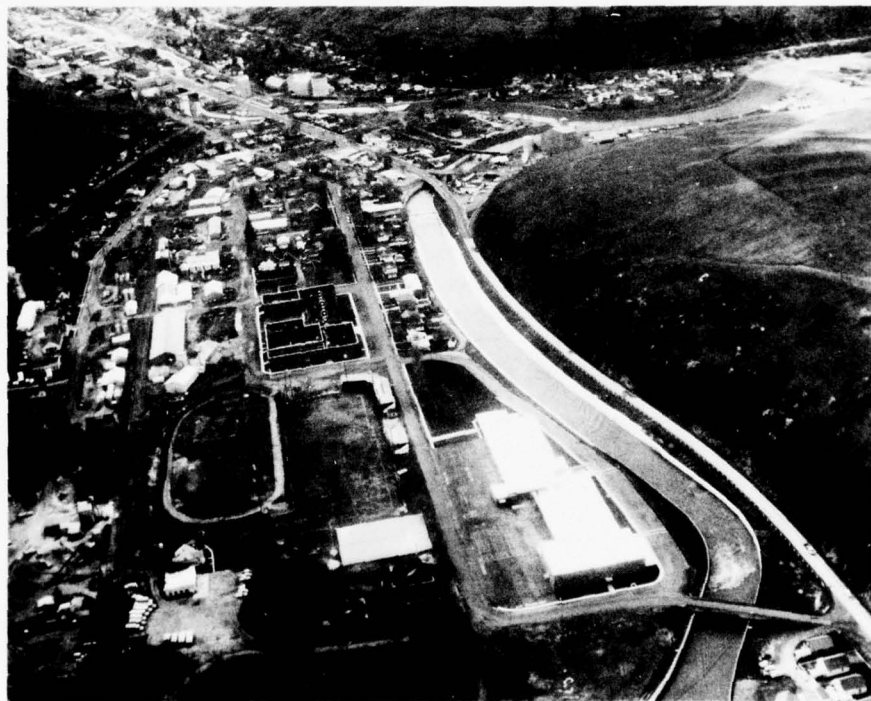
Flood Control Storage

Dworshak Dam on the North Fork of the Clearwater River will be regulated on a forecast basis for control of floods on the lower Columbia River, see table 82, when it becomes operational in 1971. Dworshak Reservoir will have a total usable storage of 3,400,000 acre-feet of which 2,000,000 acre-feet will normally be available for flood control storage. The drainage area above the project is 2,440 square miles. The four dams below Lewiston on the Snake River regulate the stream for power and navigation and provide only minimal flood flow regulation. There are about 6,200 farm ponds and small reservoirs located on minor tributary streams with an aggregate storage of approximately 10,900 acre-feet that provide incidental regulation of floodwaters.

Levees and Channels

The Federal government and local interests have constructed improved channel and levee projects at nine locations (figure 15 and table 61). The project at Colfax includes a system of concrete-lined channels about 2 miles in length that carries flows of the North and South Forks of the Palouse River and Spring Flat Creek through congested areas of the town. Earth channel improvements and revetted levees extend beyond the concrete channel. The Salmon project consists of a revetted levee on the right bank of the Salmon River. The projects at Kendrick, Mission Creek,

Culdesac, Sweetwater, and Camp Wooten consist of both channel improvements and levees. These projects provide in the aggregate 5.9 miles of channel improvement, 8.0 miles of levees, and 7.4 miles of revetment on the levee. During the early years of development of the Grande Ronde Valley, a major cutoff, known locally as the "State Ditch," was constructed on the Grande Ronde River about 5 miles below La Grande. The cutoff, which is about 4.6 miles long, bypasses nearly 37 miles of the old river channel. The cutoff now carries most of the flow of Grande Ronde River, but several tributaries enter the old channel below the head of the cutoff. The local people have constructed several other channel improvements on tributary streams in this area. Local protection works have been constructed by the Federal government on Grande Ronde River near La Grande, Catherine Creek at Union, South Fork Clearwater River at Kooskia and Stites, Orofino Creek at Orofino, Lawyers Creek at Kamiah, and other locations. Because these projects provide a relatively low degree of protection and their integrity is questionable, they are not listed in table 61.



Flood control channel on Palouse River at Colfax, Washington. (USCE)

Table 61 - Levee and Channel Projects, Subregion 6

Location	Stream	Length of Channel Improvement	Levees Miles	Length Revetment	Design Freq. Years
		Miles		Miles	
Salmon, Ida.	Salmon R.	0.0	1.2	1.2	200
Colfax, Wash.	Palouse R.	3.8 ^{1/}	1.9	1.9	SPF ^{2/}
Kendrick, Ida.	Potlatch R.	0.3	0.7	0.7	100
Kendrick, Ida.	Bear Cr.	0.2	0.2	0.2	200
Mission Creek, Ida.	Mission Cr.	0.1	0.4	0.3	SPF
Culdesac, Ida.	Lapwai Cr.	0.6	0.6	0.6	SPF
Sweetwater, Ida.	Lapwai Cr.	0.6	2.6	2.3	200
Camp Wooten, Wash.	Tucannon R.	0.3	0.4	0.2	200
State Ditch	Grande Ronde	4.6	-	-	-
Minor trib. streams		425.0	21.0	400.0	^{3/}

^{1/} Includes concrete-lined channels about 2 miles in length.

^{2/} Standard project flood.

^{3/} Degrees of protection afforded by these works vary. Considered to be 10 years or less.

Watershed Protection

Almost 1.2 million acres of cropland receive adequate treatment to reduce erosion and sedimentation and assist in the reduction of surface runoff. The practices which are most effective in this subregion include conservation cropping systems on 1 million acres, crop residue use on 1 million acres, stubble mulching on 233,000 acres, and 349 miles of diversions and terraces.

Forest land treatment practices include the installation of gully plugs and sediment traps and seeding on nearly 6,000 acres of eroding soils, plus the rehabilitation of nearly 3,000 miles of roads and trails.

Rangeland practices of particular significance include grass seeding on 218,000 acres, brush control on 68,000 acres, and excessive grazing reduced on 4.7 million acres.

It is estimated that the soils of Subregion 6 have a water holding capacity of at least 11,055,000 acre-feet, or an average of 5.93 inches over the entire watershed. With proper land treatment and under ideal climatic conditions this storage would be useful in controlling or retarding runoff. Additional information on land treatment is included in Appendix VIII, Land Measures and Watershed Protection.

Flood Plain Regulation

The Corps of Engineers prepared a flood plain information report covering a 6-mile reach of Clearwater River in the vicinity of Orofino at the request of officials of Clearwater County and Orofino. In the Moscow area, a flood plain information report is being prepared for a 4.9-mile reach of Paradise Creek in a cooperative program with the University of Idaho. A flood plain information report on the South Fork of Palouse River and Missouri Flat Creek has been prepared for the city of Pullman. Flood hazard information has also been provided to Washington State University at building sites in Pullman. Flood hazard information has been provided for construction sites in the La Grande area. The General Services Administration has been given flood information for Federal buildings at various locations throughout the subregion.

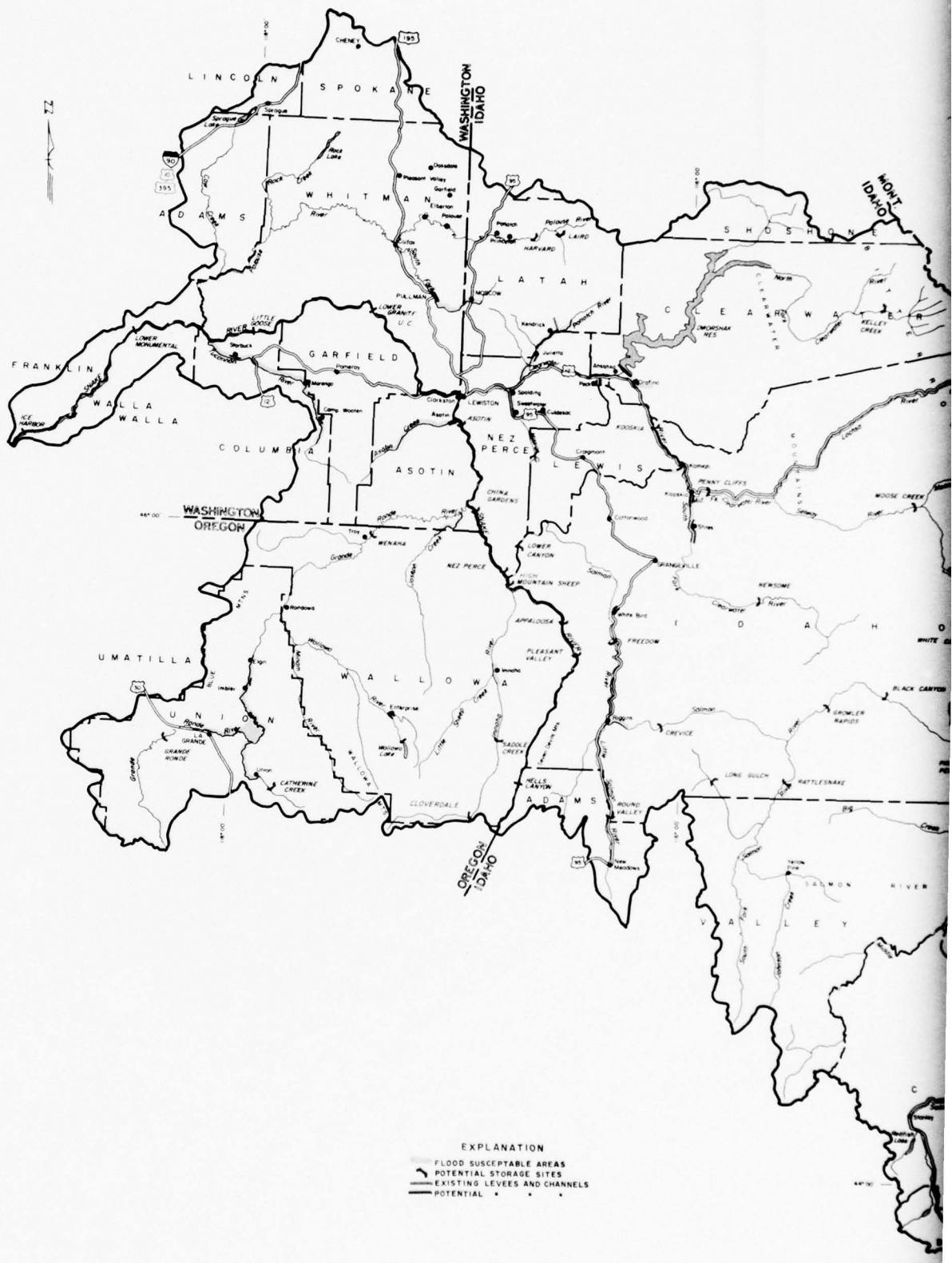
Flood Forecasting and Emergency Operations

Flood forecasts are issued by the National Weather Service for key stations on the larger streams in the subregion. Table 62 shows the key river locations, the flood stage and corresponding streamflow, and the Weather Service River District responsible for that specific station.

Table 62 - Flood Warning Forecast Points, Subregion 6

<u>Location</u>	<u>Stream</u>	<u>Flood Stage (feet)</u>	<u>Streamflow (cfs)</u>	<u>Weather Service River District Office</u>
Salmon, Ida.	Salmon R.	6.5	10,000	Boise
White Bird, Ida.	Salmon R.	29.7	80,000	Boise
La Grande, Ore.	Grande Ronde R.	5.6	4,000	Portland
Spalding, Ida.	Clearwater R.	18.0	110,000	Boise
Clarkston, Wash.	Snake R.	38.1	325,000	Portland

Flood warnings are issued when forecasts indicate that near bankfull stages are expected. Warning stage could be from 1 to 3 feet below actual flood stage. When the flood stage becomes critical, forecasts are issued at 24-hour intervals or more frequently if weather conditions dictate. Forecasts are released until streams recede to below bankfull stages and all danger is past. In addition to the forecast points listed in table 62, flood warnings are made for numerous smaller streams when flood emergencies arise. The flood forecasts are disseminated to state, county, and city authorities; Federal agencies, civil defense officials; and news media.



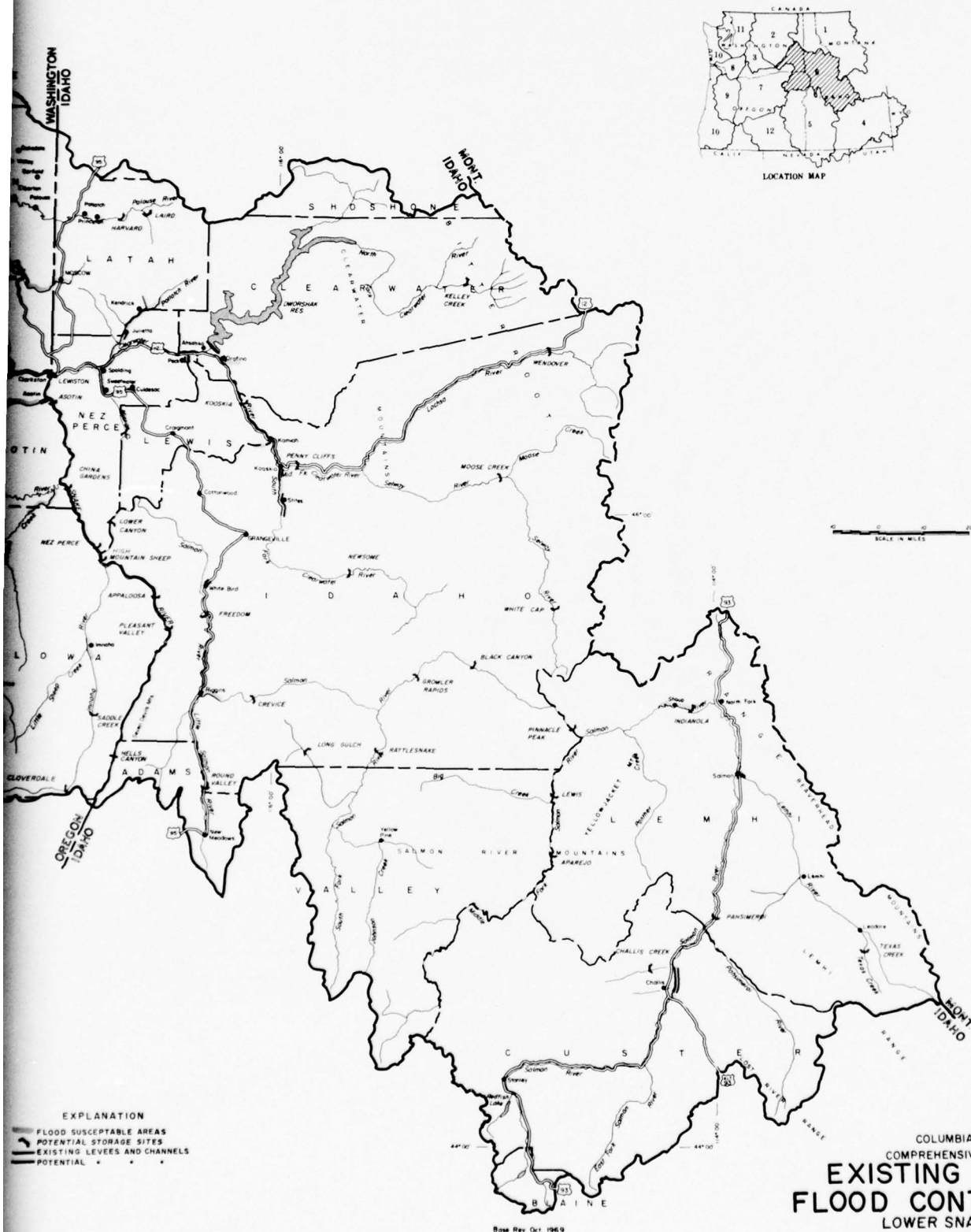


FIGURE 15

Flood emergency operations have prevented damages in a number of communities including Salmon, White Bird, Kooskia, Stites, Orofino, Peck, Kendrick, Kamiah, Colfax, Pullman, Asotin and La Grande. The emergency operations generally consist of sand-bagging, raising, and strengthening existing levees; and evacuation of people, personal effects, and livestock. The type of flood fight organization in any particular locality depends on the extent of State and Federal assistance requested by community officials and the degree of the flood threat. Usually the local Civil Defense officials, county and city officials and law enforcement agencies, National Guard, and Corps of Engineers work together to carry out emergency operations.

Accomplishments

Storage

Upstream storage projects and irrigation diversions in Subregions 4 and 5 regulate flood flows on the Snake River in Subregion 6. This is evident in the difference between natural (195,000 cfs) and regulated (60,000 cfs) standard project floods



Rendering of Dworshak Dam as completed. (USCE)

at Oxbow Dam, just upstream from Subregion 6. Dworshak Reservoir on the North Fork Clearwater River will substantially regulate flood flows on the Clearwater River from the confluence of the North Fork downstream to the mouth and will be an integral part of the reservoir system for control of the main Columbia River, see table 82. The planned operation of Dworshak Reservoir will reduce the standard project flood at Spalding from 260,000 cfs to 150,000 cfs. The size of the flood plain below the confluence of the North Fork will be reduced from 1,900 acres to 300 acres, and average annual damages along this reach of Clearwater River will be reduced from the existing \$379,000 to \$35,430. Other than Dworshak Reservoir, there is no storage project in Subregion 6 that significantly regulates flood flows.

Levees and Channels

Improved channel and levee projects prevent average annual damages estimated at \$542,830. These damages prevented amount to about 30 percent of the average annual damages that would occur if there were no prevention measures.

Flood Emergency Operations

Emergency operations have been effective in preventing flood damages in urban areas. However, little is known about the magnitude of the damages that have been prevented. Records show that emergency operations during the floods in December 1964 and January 1965 prevented an estimated \$653,000 in damages.

Summary of Accomplishments

Data on flows, acreage in the flood plains, and damages for both "without" and "with" flood control projects are listed in table 63.

Table 63 - Project Accomplishments, Subregion 6

Stream	Station	Acres in Fld. Plain ^{1/}		Ave. Ann. Damages	
		w/o Proj.	w/Proj.	w/o Proj.	w/Proj.
Snake R.	Clarkston		2/	\$ 184,400	\$ 1,000
Imnaha R. ^{3/}	Halfway		2/	2,000	2,000
Salmon R. ^{3/}	Salmon		2/	71,700	53,000
Grande Ronde R. ^{3/}	Nr. La Grande	58,407	58,407	357,000	357,000
Asotin ^{3/}	Asotin		2/	10,000	10,000
Clearwater R.	Spalding	4,000	2,242	667,000	291,000
Tucannon R. ^{3/}	Starbuck		2/	10,800	9,700
Palouse R. ^{3/}	Colfax	3,547	3,304	527,700	220,500
Total				\$1,830,600	\$944,200

^{1/} For standard project flood.^{2/} Not available.^{3/} Stream is not regulated.

Remaining Flood Problems

Flows from the Salmon and uncontrolled portions of the Clearwater Basin could contribute much toward formation of damaging floods on the lower Columbia River. The Snake River is entrenched in narrow canyons throughout the subregion except for a short reach in the Lewiston-Clarkston Area. Damages in that area will be nearly eliminated by the levees and other flowage works for Lower Granite Reservoir. Appreciable flood damages occur in the Grande Ronde, Clearwater, and Palouse River basins. Other principal tributaries flow through relatively undeveloped country, or are deeply entrenched in canyons where little damage can occur. Data on average annual damages and acreages in the flood plains are listed in table 64.

Table 64 - Areas Flooded and Remaining Damages, Subregion 6 ^{1/}

Stream	Station	Minor Flooding			Major Floods			Average Annual Damages (\$)
		Flow (cfs)	Acreage in Flood Plain		Flow (cfs)	Acreage in Flood Plain		
			Urban	Rural		Urban	Rural	
Snake R.	Clarkston	325,000		2/	350,000		2/	1,000
Imnaha R.	Halfway	2/		2/	2/		2/	2,000
Salmon R.	Salmon	8,500		2/	10,000		2/	53,000
Grande Ronde R.	La Grande	4,000	30	5,670	7,000	100	20,500	357,000
Asotin Creek	Asotin	4,000		2/	5,000		2/	10,000
Clearwater R.	Spalding	110,000	90	45	125,000	180	160	291,000
Tucannon R.	Starbuck	4,000		2/	8,000		2/	9,700
Palouse R.	Colfax	3,000	50	500	6,000	100	2,300	220,500
Minor tributaries						1,800	176,000	3,647,000

^{1/} With 1970 flood control facilities and 1967 prices and economic development.^{2/} Not available.

Snake River

Flood damages in the Lewiston-Clarkston area will be largely eliminated when Lower Granite Dam is completed in about 1974. Because the Lower Granite pool elevation in the Lewiston-Clarkston area is higher than normal river level, a system of levees designed as an integral part of the lower Granite project will be required. These levees will provide a high degree of flood protection to the towns of Lewiston and Clarkston. Damages along the Snake River in other areas are relatively minor.

Imnaha River Basin

Flood damages in the Imnaha River Basin are of relatively little consequence because the river is in a canyon throughout much of its length. Some pasturelands are flooded and developed campgrounds, forest access roads, and bridges are damaged.

Salmon River Basin

The Salmon River is confined to narrow rock canyons throughout most of its length. The relatively little development that exists in the basin is concentrated primarily in the vicinities of Challis, Salmon, Riggins, and White Bird. All of these towns have properties that are damaged by floods. There are a few scattered ranches along the Lemhi and Little Salmon Rivers and Whitebird Creek which have pasturelands in the flood plains.

Grande Ronde River Basin

The exceptionally flat river gradient between La Grande and Elgin on the upper reaches of the Grande Ronde River is the major cause of widespread flooding in that area. Damaging floods occur almost yearly in the Grande Ronde Valley from La Grande and Union to Elgin, and often flood extensive parts of the principal agricultural areas. The majority of the damages occur along the Grande Ronde River, lower Catherine Creek, and lower Willow Creek. Below Elgin there are no significant flood problems along the Grande Ronde River because bottom lands are narrow and largely uninhabited. Less extensive and less frequent flooding occurs on Lower Joseph Creek and in the Wallowa Valley. High velocities cause considerable bank erosion and some channel shifting on these streams almost every year. Under major flood conditions, portions of the towns of La Grande, Enterprise, Elgin, Wallowa, and Union are inundated.

Asotin Creek

Flood damages occur throughout the length of Asotin Creek. In the town of Asotin, which is located at the mouth of the creek, residences, the sewage disposal system, the city park and two marinas are in the flood plain. Upstream from Asotin, county roads, farmsteads, and agricultural lands are damaged.

Clearwater River Basin

Although sparsely populated, the Clearwater River Basin is vulnerable to high water because much of the development is located in the narrow valleys. The Clearwater River near Orofino causes damage when flows reach 50,000 cfs and general flooding occurs at 65,000 cfs. Flows of 35,000 cfs cause flooding on the North Fork near the mouth; otherwise, this stream is in a well-defined channel in a narrow mountain valley with little development. The principal tributaries have not experienced simultaneous peak flows. Flood damages occur mainly at the towns of Juliaetta, Stites, Kooskia, Kamiah, and Orofino, which are situated in narrow valleys. Less important damages occur to farmlands, roads, and railroads between Stites and Lewiston. The levees associated with Lower Granite Reservoir will largely eliminate the Clearwater River flood damages to properties in Lewiston.



June 1964 flood scene at Orofino, Idaho. (USCE)

Tucannon River

The extent of flooding along the Tucannon River is minimal because of the narrow canyon in which the stream flows. Flood damage occurs to recreational developments including campsites, a fish hatchery, and several off-stream fishing ponds in the upper portion of the basin; irrigated pasture and cropland below the community of Marengo; and the community of Starbuck.

Palouse River Basin

The greatest potential for flood damage in the Palouse River Basin is at Moscow and Pullman. In Moscow, flooding from Paradise Creek damages University of Idaho student housing and residential and commercial property. In Pullman, the majority of the business district as well as a portion of the residential area is subject to infrequent flooding from the South Fork Palouse River and Missouri Flat Creek. Several small communities in the basin such as Elberton, Palouse, Princeton, Garfield, Pleasant Valley, Oakesdale and Potlatch have areas in the flood plain. Both the South Fork and the main river follow deeply entrenched beds throughout a large part of their course. However, sheet erosion is a serious problem. The principal flood damages to agricultural areas consist of bank erosion, inundation, and debris deposition on pastureland, and damage to transportation facilities.



Main Street, Pullman, Washington, February 1948. (USCE)

Streambank Erosion

Serious streambank erosion occurs on an estimated 2,700 miles of streams and the total annual loss is 3,300 acres. Essentially all of the eroded material remains in the subregion and most within individual stream subbasins. Annual losses associated with erosion including effect of destroyed lands, loss of reservoir and channel capacities, deposition of silt and debris, and adverse effects on aquatic life, recreation, etc., are estimated to be \$740,000 of which nearly six percent is urban and the balance rural.

Minor and Upstream Tributary Areas

In addition to the major flood plains, more than 122,000 acres of cropland, 43,000 acres of forest lands, and 11,000 acres of range and pasturelands are subject to flooding by minor and upstream tributary streams.

PROJECTIONS AND NEEDS

Projections made for the Columbia-North Pacific Region indicate that the population of Subregion 6 will increase from 163,250 in 1965 to 193,450 in 1980, 232,600 in 2000, and 274,300 in 2020, an increase of about 0.93 percent per year. Per capita income is projected to increase from a present value of about \$2,032 to \$11,900 by 2020 and total personal income from \$326 million to \$3,264 million. Most population increases are expected to occur in urban or suburban areas with rural and small town populations generally decreasing.

Flood damages in the Clearwater, Grande Ronde, and Palouse River basins account for more than 90 percent of the total damages that occur throughout Subregion 6. The present level of flood damages, not including the upstream tributary areas, is \$944,200 and is estimated to increase to \$1,356,000, \$2,223,000, and \$3,775,000 in 1980, 2000, and 2020, respectively (table 65). The estimates of future damage levels are based on economic projections presented in Appendix VI, Economic Base and Projections.

The growth factors for agricultural damages were developed from crop yield projections for specific crops presently raised in the flood plains. Rural, nonagricultural damages were projected at the per-capita income growth factor for the subregion. For projecting urban, commercial, and industrial damages each specific stream reach was analyzed. The growth factors for these damages in the towns that have populations greater than 2,500 were selected on the basis of past population trends of each town. The populations of La Grande and Moscow have been nearly stable in recent

years except for increases in college student enrollment so the per capita income growth factor was used for projecting damages. For Salmon and Pullman, which are the only other towns in Subregion 6 with populations greater than 2,500 and lands in the flood plain, a composite growth factor between the total personal income and per capita income growth factors was used for projecting damages. Thus, the fact that the past growth for these towns has been less than that of the subregion was reflected in the projections. The communities with less than 2,500 population were included in the rural nonagricultural category. These economic growth factors were applied to average annual damages under present conditions of protection and economic development to obtain estimates of future damage levels, which are shown in table 65.

Table 65 - Current and Projected Flood Damages, Subregion 6

Stream Basin	Average Annual Flood Damages, \$1,000, 1967 Price Levels					
	1967 Development			Projected Development		
	Rural	Urban	Total	1980	2000	2020
Snake R.	0	1	1	1	2	4
Imnaha R.	1	1	2	3	4	7
Salmon R.	36	17	53	72	105	158
Grande Ronde R.	232	125	357	488	715	1,076
Asotin Cr.	10	0	10	14	20	30
Clearwater R.	109	182	291	429	745	1,327
Tucannon R.	5	5	10	14	24	43
Palouse R.	43	178	221	335	608	1,130
Streambank erosion all basins	696	44	740	777	833	940
Minor tributary areas	5,489	158	5,647	4,705	5,835	6,966
Total	4,621	711	5,332	6,838	8,891	11,681

Streambank Erosion

The annual loss of land due to streambank erosion is not expected to change except as influenced by corrective measures. The value of land loss and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being primarily based on removal costs, remain constant. Future annual damages from erosion will amount to \$777,000 in 1980, \$833,000 in 2000, and \$940,000 in 2020.

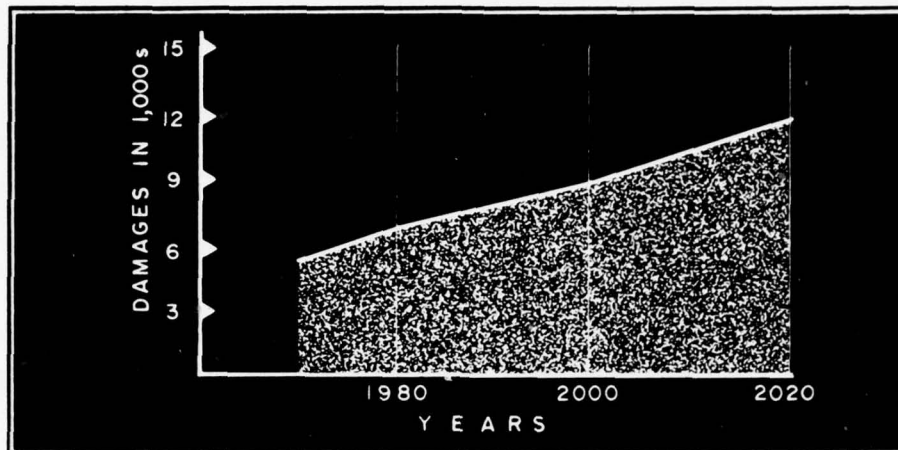


Figure 16. Projected Average Annual Flood Damages, Subregion 6.

MEASURES REQUIRED TO SATISFY NEEDS

Measures that can be taken to help alleviate flood damages include storage, channel and levee works, nonstructural measures, or combinations thereof. Storage capacities needed in specific areas to control floods of standard project flood magnitude to nondamaging stages are listed in table 66. These storage volumes were estimated without considering economic feasibility or availability of satisfactory storage sites although, as shown in table 67, sites are available which would physically meet most of the storage needs.

Control of floods by storage alone to the extent that a standard project flood is held to nondamaging stages is unlikely in most areas. However, lesser amounts of storage in combination with local protection projects and nonstructural measures may adequately protect most areas.

Nonstructural measures, including flood plain zoning, flood proofing, watershed treatment, forecasting, and flood fight operations, could help reduce future damages on most of the streams even though most of the flood plain areas will continue to be utilized for agriculture. In the rural areas future farm buildings can be located to minimize flood damages, and roads, bridges, and utilities can be suitably flood proofed. With adequate warnings, livestock and mobile equipment can be moved to safe locations.

Table 66 - Storage Needed to Eliminate Flood Damages
Caused by Major Streams, Subregion 6

<u>Stream</u>	<u>Principal Flood Problem Area</u>	<u>Bankfull Capacity (cfs)</u>	<u>Upstream Storage Needed for Flood Control 1/- (Ac.-Ft.)</u>
Imnaha River	Lower Valley	3,500	50,000
Salmon River	Challis-Salmon	8,500	1,300,000
Grande Ronde River	La Grande-Elgin	4,000	260,000
Asotin Creek	Asotin	4,000	50,000
Clearwater River	Orofino-Riverside	50,000	1,600,000
South Fork Clearwater River	Stites-Kooskia	15,000	220,000 2/
Orofino Creek	Orofino	2,000	65,000 3/
Tucannon River	Starbuck	4,000	80,000
Palouse River	Above Colfax	4,000	100,000
S. F. Palouse River	Pullman	3,000	30,000
Missouri Flat Creek	Pullman	500	7,000
Paradise Creek	Moscow	500	4,000

1/ Except as noted, the storage needed is that required together with existing storage to control a flood of standard project magnitude to nondamaging stages. Storage needed does not consider availability of sites or economic feasibility and must be fully effective for flood control.

2/ Assumes existing emergency levees maintained.

3/ Not effective in lower reach of creek where flooding results from backwater from the Clearwater River.

Flood control measures that could reduce damages in specific problem areas are discussed below.

Snake River

Although flood damages on the middle and lower Snake River are minor, there is potential for developing a large amount of storage on the middle reach of the river - between Lewiston, Idaho, and Hells Canyon Dam. Development of storage sites could contribute to regulation of floodflows on the lower Columbia River, but the added downstream value of such regulation is small in view of other storage already developed - see Subregion 8. Further, this reach of the Snake River has been designated for inclusion in the the National Wild and Scenic Rivers System. (3)

Grande Ronde River Basin

Two multiple-purpose reservoir projects are authorized for construction in the Grande Ronde River Basin. (9) One is to be located on the Grande Ronde River about 11 miles upstream from La Grande and the other on Catherine Creek about 8 miles upstream from Union. The reservoirs would provide a substantial level of

Table 67 - Potential Storage Sites, Subregion 6 1/

Basin & Stream	Damsite	Potential Storage (Acre-Feet)	Discussion
Snake River	Pleasant Valley	1,050,000	Flood control storage on Snake R. in Subregion 6 would primarily benefit Lower Columbia River. Other possible uses for Snake R. projects include power, navigation, water quality, recreation, and fish and wildlife.
	Appaloosa	2,410,000	
	High Mt. Sheep	3,600,000	
	Nez Perce	6,000,000	
Salmon River Basin			
Salmon River	Lower Canyon	3,700,000	Most of the flood damages in Salmon R. Basin occur in the upper basin - above the town of North Fork, Idaho. Therefore, storage development on the segment of the Salmon R. from North Fork, Idaho, to its confluence with Snake R., & tributaries thereof, where these damsites are located, would have little effect on flood damages in the basin. Middle Fork of Salmon R. is designated as a national wild & scenic river. The segment of the Salmon R. from North Fork, Idaho, to its confluence with Snake R., and tributaries thereof, is designated for potential addition to the national wild & scenic river system. (3)
Little Salmon R.	Round Valley	230,000	
Salmon River	Crevice	1,480,000	
S. Fk. Salmon R.	Rattlesnake	285,000	
Secesh River	Long Gulch	183,000	
Salmon River	Growler Rapids	425,000	
Salmon River	Black Canyon	600,000	
Salmon River	Pinnacle Peak	790,000	
Salmon River	Indianola	365,000	
M. Fk. Salmon R.	Lewis	450,000	
M. Fk. Salmon R.	Aparejo	1,360,000	
Lemhi River	Texas Creek	19,000	Texas Creek Damsite is located in headwaters of Lemhi River.
Salmon River	Pahsimeroi	1,500,000	A project at the Pahsimeroi site could help reduce damages downstream to North Fork, Idaho. Other uses include irrigation, power, and recreation.
Challis Creek	Challis Creek	10,600	Principally an irrigation project, it also would provide recreation, fish and wildlife enhancement and flood control benefits.
Imnaha River Basin			
Imnaha River	Cloverdale	67,000	Other possible uses for storage on Imnaha River are power, irrigation, and recreation.
	Saddle Creek	5,000	
Grande Ronde R. Basin			
Grande Ronde R.	Grande Ronde	160,000	Grande Ronde and Catherine Creek projects are authorized for construction. They will help meet flood control, irrigation, water supply, water quality, recreation, and fishery needs in the Grande Ronde River Basin.
	Catherine Creek	61,000	
Grande Ronde	Wenaha	900,000	Being located in lower reach, Wenaha project would provide flood control benefits primarily to lower Columbia River. Could also benefit power, recreation, and water quality.
Clearwater River Basin			
Clearwater River	Kooskia	4,600,000	Kooskia Res. would inundate a reach of the river that is designated as a national wild and scenic river. (3)
M. Fk. Clearwater R.	Penny Cliffs	2,300,000	Penny Cliffs, Moose Creek, White Cap, and Wendover Damsites are located on national wild and scenic rivers. (3)
Selway River	Moose Creek	830,000	
Selway River	White Cap	360,000	
Lochsa River	Wendover	405,000	
S. Fk. Clearwater R.	Newsome	360,000	Would reduce flood damages in the Kooskia-Stites reach of the South Fork and on Clearwater River. Other possible uses include power and recreation.
Kelly Creek (Trib. of N. F. Clearwater R.)	Kelly Creek	780,000	Would reduce flood damages on Clearwater River. Other possible uses include power and recreation.
Palouse River Basin	Harvard	40,000	Would reduce flood damages along the North Fork and help meet the recreation, water supply, water quality, and irrigation needs of the area.
	Laird	50,000	Alternative to Harvard.
Minor tributaries	9,200 farm ponds & reservoirs	15,300	Flood control incidental to other water uses.

1/ This information is furnished for possible use in plan formulation and includes the total storage capability at many sites. The amount that would be usable for flood control would in many cases be considerably less.

flood protection throughout the Grande Ronde Valley from La Grande and Union to Elgin. Flows up to standard project magnitude would be controlled to bankfull capacity at La Grande and Union. The total flood damages in the basin would be reduced by about 65 percent.

These reservoirs are essential to achieving any degree of flood damage reduction in the valley. Some additional damage reduction could be achieved by removing some rock ledges in the river bottom near Elgin. This work, however, should be carefully considered because it might cause more harm than good by lowering the ground water table. The flood control needs on lower Willow Creek could be met by about 10 miles of channel improvement at an estimated cost of \$175,000.

Two channel improvement and levee projects on the Wallowa River near Wallowa and Enterprise would alleviate the most serious flood problems in the Wallowa subbasin at an estimated cost of \$900,000.

Flood plain zoning in the vicinity of La Grande and other towns in the basin should be used as an interim measure to minimize growth of flood damage potential until such time as structural measures for flood protection are constructed.

Salmon River

The Salmon River Basin has tremendous potential for storage development. (7) However, most of the potential storage sites are located below North Fork, Idaho, and would contribute little to flood damage reduction in the Salmon Basin. Because flood damages along the Salmon River occur chiefly in the reach from Challis to Shoup, flood control storage would have to be located in the upper portion of the basin to be effective in the Salmon River Basin. About 1,300,000 acre-feet of additional storage would afford complete flood control. Storage developed below North Fork would contribute to the control of floods on the lower Columbia River.

Channel and levee work costing about \$1,000,000 would alleviate the flood problem in the vicinity of Challis. An existing channel project at Salmon protects that town from flows on the Salmon River, but a portion of the town receives damages from high flows on the Lemhi River. Either upstream storage on the Lemhi River or channel work on the lower reach at Salmon would alleviate flooding. The only other area in the Salmon River drainage where floods inflict substantial damages is on Whitebird Creek at White Bird. For comprehensive protection existing

emergency levees would have to be raised and strengthened. White Bird lies in the bottom of a narrow valley with little available land free from floods, so there appears to be little opportunity to reduce damages by nonstructural means. However, implementation of flood plain zoning possibly could reduce future damages in the Salmon and Challis areas.

Asotin Creek

The most practicable means of reducing flood damages along Asotin Creek appears to be construction of local protection works at the town of Asotin. The magnitude of the basin's damages would not justify more than a fraction of the cost of constructing storage, so any flood control storage would have to be incidental to storage for other purposes. There is limited opportunity of reducing the growth in flood damages at Asotin by flood plain zoning because the town lies in a narrow valley bottom that has few lands outside of the flood plains available for development.

Clearwater River Basin

Flood problems in the Clearwater River Basin are mainly along the Stites to Kooskia reach of the South Fork of the Clearwater River, along the main stem from its confluence with the South Fork to the North Fork, and along Orofino Creek in the vicinity of Orofino. An additional 1,600,000 acre-feet of storage is needed in the basin to control floods up to standard project magnitude. Included in this storage is 220,000 acre-feet that is needed on the South Fork and 65,000 acre-feet on Orofino Creek. A study is currently underway to determine the feasibility of constructing local protection works on the South Fork for the towns of Kooskia and Stites. The work would entail raising and reinforcing the existing emergency levees at a cost of about \$600,000. Protecting these two towns from floods up to 200-year average frequency magnitude would reduce the total basin damages by about 13 percent. Being located at the confluence of Orofino Creek and the Clearwater River, the town of Orofino is flooded by both streams. Either upstream storage or channel improvement and levees at Orofino could protect the town. Flood damages along the main river below Kooskia are principally to railroad and highway facilities that parallel the stream. Upstream storage is the most practicable means of reducing damages along that reach.

The towns of Juliaetta, Kamiah, and Peck are flooded by minor tributaries. Channel improvements and levees appear to be the most practicable means of reducing damages in these communities. A channel project on Big Canyon Creek would cost about

\$120,000 and protect the town of Peck from floods up to a 100-year frequency and reduce the total basin damages by about three percent.

The potential for minimizing growth of flood damages through flood plain zoning is greatest at the two largest towns in the basin - Orofino and Kamiah. The Stites to Kooskia area and the smaller towns are located in narrow valley bottoms where there is little land outside of the flood plain suitable for developing.

Tucannon River

The majority of the flood damages along the Tucannon River occur at the community of Starbuck, which is located only 4 miles above the mouth. Storage could be developed in the headwaters area but such storage would regulate flows from only a small portion of the drainage above Starbuck. It therefore appears that increasing the capacity of the channel at Starbuck is the most reasonable structural measure that could be taken to significantly reduce damages in the basin. A channel improvement and levee project providing protection to the community from floods up to 100-year frequency magnitude would reduce total damages in the basin by two-thirds and cost about \$275,000. Future flood damages could be minimized by nonstructural measures at Starbuck. Although about 90 percent of the present town is within the flood plain, there is adjacent flood-free land across State Highway 261 to the northeast available for future development.

Palouse River

The two areas that receive the major portion of the flood damages in the Palouse River Basin are at Moscow from Paradise Creek and at Pullman, from the South Fork Palouse River and Missouri Flat Creek. The possibility of reducing flood damages in these two critical areas by reservoir storage appears to be remote because there are no good damsites on either Paradise Creek or the South Fork. Also, dam construction in these areas has been vigorously opposed by the local people.

The most feasible solution for the flood problem at Moscow appears to be either a diversion of Paradise Creek into the South Fork Palouse River above town, or a combination project consisting of channel rectification and a bypass channel through the University of Idaho campus.

A flood channel project through Pullman is authorized but inactive. The project plan provides for channel rectification and levee construction along both the South Fork Palouse River and Missouri Flat Creek. The channel was designed to carry the peak flow of the standard project flood. The project, estimated to cost approximately \$3,000,000, would prevent about 40 percent of the total average annual damages in the Palouse River Basin.

Flood plain zoning could help reduce future damages at both Moscow and Pullman. Although there is already extensive development along the streams within the cities, development could occur in adjacent flood plains if no restrictions are applied. In fact, recent residential construction in the area east of Moscow is already infringing on the flood plain.

Flood damages on the North Fork Palouse River total less than 20 percent of the damages in the basin, and most of the damages occur in the agricultural reach extending from Harvard, Idaho, to Colfax, Washington. Storage appears to be the only practical structural means of reducing damages on the North Fork.

Minor and Secondary Tributary Streams

It is estimated that prior to 2020 the needed levee, channel, and bank protection improvements on minor and secondary tributary streams will comprise 50 miles of levees, 1,000 miles of stream channel improvements, 8 miles of stream channel stabilization, 900 miles of streambank protection, and 360 miscellaneous stream structures. Additional information on these and land treatment measures is included in Appendix VIII, Land Measures and Watershed Protection.

Land Treatment Measures

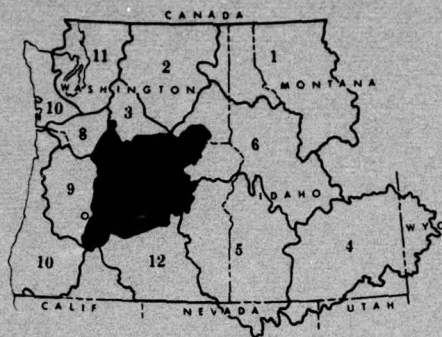
Cropland treatment measures needed to supplement existing practices for control of flood damages include 1,247,000 acres of crop residue use, 1,040,000 acres of conservation cropping systems, 217,000 acres of stubble mulching, 321 miles of diversions and terraces, and 481,000 acres of irrigation water management. Forest land treatment measures include 264,500 acres of erosion control treatment and 3,890 miles of road and trail restoration. Rangeland practices include 224,800 acres to be seeded to grass, 677,500 acres of brush control, and excessive grazing control on 60,400 acres.

Comprehensive Watershed Treatment

Comprehensive treatment programs comprising land measures and small flood control structures should be applied to 62 watersheds which have a total of 119,100 acres subject to flood damages. The works on these watersheds are included in the subregion totals of small flood control structures and land treatment measures cited above.

Bank Erosion

Approximately 15 percent of the seriously eroding stream-bank will require treatment prior to 2020. Along many of the smaller streams and in headwater areas, adequate protection can be achieved by use of vegetative measures at an average cost of \$8,000 per mile. Structural measures, predominantly riprap, will be required on the larger streams. It is estimated that riprap protection would cost \$40,000 per mile and that concrete retaining walls would cost \$200,000 per mile. Total costs of bank protective works in Subregion 6 are estimated to be \$4,500,000 through 2020.



LOCATION MAP

7 20-000000

SUBREGION 7

MID-COLUMBIA

GENERAL

Location and Extent

Subregion 7, the Mid-Columbia Basin, includes all areas draining into Columbia River in the reach below the mouths of Yakima and Snake Rivers downstream to Bonneville Dam. Its length and width are 300 and 200 miles, respectively. The total area is 29,606 square miles, of which 5,469 square miles are in Washington and 24,137 in Oregon. The subregion is bounded by Subregions 8 and 9 on the west, the Oregon Closed Basin, Subregion 12, on the south, the Snake River drainage Subregions 5 and 6 on the east, and Subregion 3 on the north.

Topography

Much of the perimeter of Subregion 7 is rough and mountainous. The Cascade Range on the west includes six peaks above 10,000 feet and, by contrast, the range is cut almost to sea level by the Columbia Gorge. The Blue Mountains on the east have several peaks above 8,000 feet. Foothills from the mountain ranges extend into the subregion and form the northern and southern boundaries. Gentle rolling plateaus ranging in elevation from 700 to 5,000 feet occupy much of the interior. Much of the rolling land, particularly in the John Day and Deschutes Basins and along the Columbia River, is sharply cut by canyons with steep, rocky walls.

Climate

The climate, except the mountainous areas and the valleys of White Salmon, Wind, and Hood Rivers, is semi-arid and characterized by cool-to-cold winters and warm, dry summers. About 75 percent of the precipitation falls between November and April, and rainfall during July and August is generally limited to occasional localized convective-type storms. Winter storms generally result in heavy precipitation near the crest of the Cascade Range and on the western slopes of other mountains. Normal annual precipitations range from 9 to 15 inches on the lowlands and in the rain shadow of the Cascades to 60 to 80 inches on the higher mountain areas. As much as 250 to 350 inches of

snow occurs annually in the upper Cascades, and from 100 to 150 inches in the Blue Mountains. At elevations above 5,000 feet, snow normally remains on the ground from December through May. On rare occasions warm winter storms combine snowmelt and heavy rainfall at all elevations. These storms and abnormally rapid spring snowmelt produce floods on the major tributaries. Localized flooding is caused by summer convection storms. Temperature characteristics generally vary with elevation but also reflect the maritime climate controls as modified by the intervening Coast and Cascade Ranges. Temperatures above 90°F. are common at lower elevations during the summer but decrease in frequency at higher elevations. Subfreezing temperatures are common in winter except in the lower Cascade valleys, where rainfall predominates.

Economic Development

The population in 1965 was 210,500, including 147,100 in Oregon and 63,400 in Washington. A generalized distribution is 47 percent urban and 53 percent rural. The number of people employed in the subregion in 1960 was about 73,100. Those employed in commodity producing industries included: agriculture, forestry, and fisheries - 12,500; and manufacturing - 12,700. Industries based on forest products and the processing and packing of farm produce have a definite effect on the economy. The natural beauty and unusual geologic structure of the Columbia River Gorge are a major recreational attraction. Extensive use is made of water facilities for pleasure craft touring, local day-use, boating, swimming, and fishing. About 42 percent of the land is publicly owned. The approximate pattern of land use is: cropland, 20 percent; rangeland, 33 percent; forest, 44 percent; other, 3 percent. The main crops are wheat, feed grains and forage, livestock, vegetables, and fruit.

Cities with populations of 10,000 or more include Walla Walla, Pendleton, Bend, and The Dalles. There are eight towns with populations between 2,500 and 10,000, and 20 with 500 to 2,500. The southeastern portion of the subregion includes large areas that are virtually uninhabited. The Tri-Cities area, Pasco, Kennewick, and Richland, Washington, is located at the junction of Subregions 2, 6, and 7. Kennewick is in Subregion 7, but none of these cities is included in the economic subregion.

Interstate 80N (U. S. 30) follows the south bank of the Columbia River from the gorge to Boardman, then continues easterly through Pendleton and towards La Grande and to Snake River Valley. The subregion is also crossed by U. S. 20 and 26 in the east-west direction and U. S. 97 and 395 in the north-south direction.

Other State and county roads provide all-weather access to all populated areas.

Rail service is provided by trunk lines of the Union Pacific, and Burlington-Northern Railroads and several spur lines. The Columbia River is navigable for vessels with drafts to 14 feet and is used for barges hauling wheat, petroleum products, cement, and other commodities.

Streams

The Columbia River flows westward through northern part of Subregion 7. The river enters the subregion at about elevation 340 and falls about 330 feet through McNary, John Day, The Dalles, and Bonneville Dams. Slack water extends throughout this reach of the river. The principal tributaries of the Columbia River in Subregion 7 are the Klickitat and White Salmon Rivers from the north; the Walla Walla River from the east; Umatilla River from the southeast; and the Hood, Deschutes, and John Day Rivers from the south. Table 68 lists pertinent data on the principal streams. For additional information on streams and streamflow characteristics, see Appendix V.

Table 68 - Streamflow Summary for Selected Sites, Subregion 7

Stream	Total Drainage Area (Sq. Mi.)	Enters Col. R. at mile	Gage Location	Gage Drainage Area (Sq. Mi.)	Mean Annual Flow 1/ (cfs)	Momentary Flow 1/ Max. Min. (cfs) (cfs)	
Walla Walla	1,760	314	Touchet	1,657	555	33,400	2
Umatilla	2,290	289	Umatilla	2,290	420	19,800	0
John Day	7,840	218	McDonald Ferry	7,580	1,985	42,800	4
Deschutes	10,500	204	Moody	10,500	5,186	75,500	2,400
Klickitat	1,350	180	Pitt	1,297	1,565	31,000	445
Hood River	329	170	Hood River	329	1,072	34,000	165
White Salmon	386	168	Underwood	386	1,176	9,700	158
Columbia			Bonneville Dam	240,000	177,400	1,240,000 2/	35,000

1/ From Appendix V.

2/ Same as 1894 flood recorded on The Dalles gage.

Flood Characteristics

Floods of the Columbia River do not cause significant damages in Subregion 7. However, floods on tributaries due to heavy rainfall, melting snow, or a combination of the two may occur at any time between December and June and do cause serious damage. These floods are short duration, usually reaching a crest within a day following the maximum precipitation. The duration of the crest stage is a matter of hours and the flows recede to normal within a few days. Floods due to thunderstorms over small areas occasionally occur during the summer months and result in damaging freshets.

Pertinent data on bankfull and major flood stages and flows at key locations throughout the subregion are shown on table 69.

Table 69 - Bankfull and Major Flood Stages
Subregion 7

Stream	Station	Bankfull			Major Flood		
		Stage (ft.)	Q (cfs)	Freq. (yr.)	Stage (ft.)	Q (cfs)	Freq. (yr.)
Walla Walla R.	Touchet	7.5	3,500	1	12.3	12,000	5
Umatilla R.	Yoakum	7.7	6,500	2	12.2	15,000	15
Willow Creek	Heppner	8.2	1,500	10	13.0	3,500	20
John Day R.	John Day	5.7	2,500	10	6.9	3,500	30
Crooked R.	O'Neil	-	3,000	-	-	-	-

HISTORY OF FLOODING

Columbia River

By far the largest recorded flood on the Columbia River was that of June 1894, although the historical flood of 1849 may have been equally large. The 1894 flood had a maximum discharge of 1,240,000 cfs at The Dalles and a maximum water surface profile roughly 30 to 35 feet above the mean low water profile from the mouth of the Snake River to Celilo. At Big Eddy, 9 miles below Celilo and at the location of The Dalles Dam, the water surface was 60 feet above mean low water. No estimates of damages during that flood are available.

The only flooding in Subregion 7 portion of the Columbia River for which damage records are available occurred in June 1948. (11) Damages amounting to nearly \$5,000,000 were recorded for the reach between the mouth of the Yakima River and Bonneville Dam. The postflood report does not furnish a detailed listing of damage locations, but indicates that considerable flooding occurred in the vicinity of Kennewick.

Walla Walla River Basin

The largest flood of record on the Walla Walla River and principal tributaries occurred in December 1964. (23) The most serious flooding occurred along Touchet River from Dayton to Waitsburg and near the mouth of Walla Walla River. Water inundated agricultural lands, and much of the business district of

Waitsburg was flooded when levees failed or were overtopped. Total damages, one-half accruing to agricultural lands, amounted to \$2,792,000. Damages prevented by developed projects were estimated to be \$1,227,000. At the Bolles gaging station, just downstream from Waitsburg on the Touchet River, the peak flow was 9,900 cfs, the maximum of record. The peak discharge on the Walla Walla River at Touchet was 33,400 cfs, also the maximum of record.

The December flood was followed by another in January 1965. In most areas the January flood peaks were not as high as those in December. The exception was Walla Walla River at Milton-Freewater, Oregon, where the peak of 9,000 cfs in January was the maximum ever recorded. Although the levees through town were severely damaged, flood fight activities prevented a levee failure. Basin-wide damages in January amounted to \$671,000 with \$975,000 in damages prevented by existing works. Flood fight activities prevented an additional \$705,000 of damages. Damages to county roads and bridges were extensive throughout Walla Walla County, amounting to \$1,500,000 for the combined December 1964-January 1965 flooding. Much of this damage was due to siltation and deposition of debris.

Walla Walla River near Touchet has produced floodflows in excess of 20,000 cfs five times since 1906.

Umatilla River Basin

The largest flood of record on the Umatilla River occurred in January 1965, and produced a peak of 19,800 cfs near the mouth of Umatilla River. The maximum flow at Pendleton occurred in December 1882, an estimated 17,000 cfs. (23)

Major flood damages were experienced in the basin during both the December 1964 and January 1965 floods. The peak discharge at Pendleton during the December flood was 13,000 cfs. The levees and channel through Pendleton contained the flood without damage. The majority of flooding occurred along the Umatilla River about 10 to 20 miles downstream from Pendleton; about 450 acres were inundated. Principal damages were at Stanfield, which was severely flooded by waters from Stage Gulch. Basin-wide damages amounted to \$828,700; damages prevented by existing works were estimated to be \$2,358,000.

During the January 1965 floods, record stages and flows were exceeded at most gaging stations. Most communities in the basin experienced some flooding and those along the Umatilla, except Pendleton were seriously flooded. The December high water

had damaged or weakened many structures, which increased the destructiveness of the January high water. Considerably larger areas of agricultural land were flooded, and damages throughout the basin were greater than during the December 1964 flood. Basin-wide damages were estimated at \$1,851,000, and damages prevented at \$5,185,000. In addition to the damages listed above, the Union Pacific Railroad reported an accumulated total during both floods of nearly \$1 million damages, due largely to sidehill runoff on Meacham Creek. McKay Reservoir on McKay Creek was particularly effective in reducing floodflows on that stream and was credited with preventing a combined total of \$1,245,000 in damages for both floods.

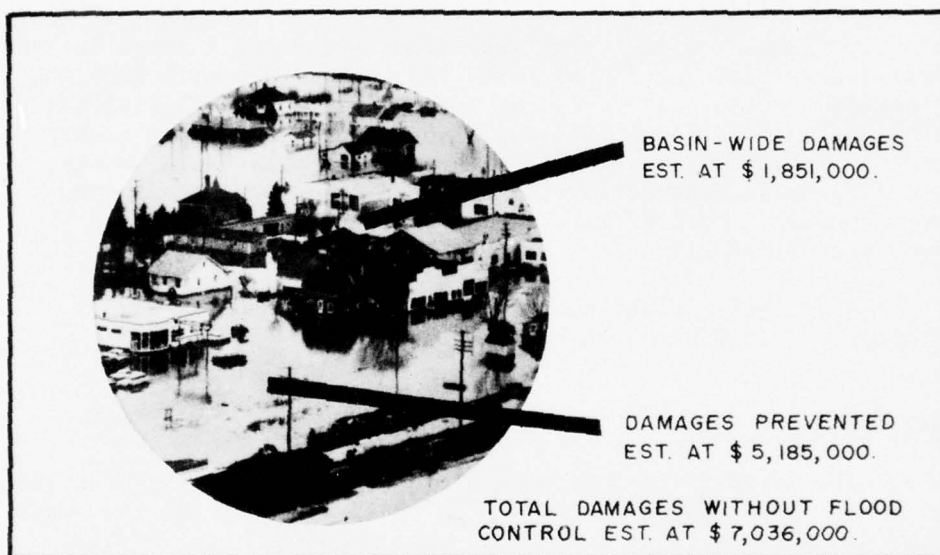


Figure 17. The Result of Flood Prevention Facilities on 1965 Flood Damages.

Three other major floods have been recorded on Umatilla River.

Willow Creek Basin

In June 1903 a cloudburst flood destroyed a large part of the town of Heppner and 247 lives were lost. (7) The flood had an estimated, but not recorded, peak discharge of 36,000 cfs. This is the sixth most disastrous flood in the history of the United States from the standpoint of the number of lives lost. During the early part of the flood, a washout from a side canyon dammed

the main stream immediately above Heppner. This dam broke during the peak of the flood and greatly increased the crest.

In December 1964, the peak discharge at the mouth of Willow Creek was 14,700 cfs, over seven times the previous flood of record. Normally dry canyons and tributaries carried excessive mud and debris loads that partially filled the river channel and increased out-of-bank flooding. Damages, amounting to \$1,240,000, were primarily from flooding of highways, railroad, farmlands, and hay and grain storage, and heavy deposition of silt and debris.

(23)



Near views of devastated areas in Heppner, Oregon, after flood of June 14, 1903. (USCE)

John Day River Basin

The maximum flood on the John Day River near the mouth, 42,800 cfs, was reached in December 1964. (23) Maximum-of-record discharges were also experienced on many tributaries. In the upper John Day valley, portions of five communities, Dayville, Mt. Vernon, John Day, Canyon City, and Prairie City, and about 70 percent of the valley floor were flooded. Flood damages were principally to agricultural lands and roads and amounted to \$4,998,000. The greatest single item of damage was the failure of the Interstate 80N bridge near the mouth, which resulted in the loss of three lives. This was the most severe general flood of record; however, cloudburst-type floods have produced greater localized flows in some of the minor tributary canyons.

The January 1965 flood was less severe, although both the North and Middle Forks experienced new record peaks. The peak discharge on the North Fork at Monument was 33,400 cfs, 50 percent greater than any flow previously recorded. Much of the upper basin was reflooded, but flood fight activities prevented some reflooding of the communities. The December flood had weakened riverbanks so that the more prolonged January flows caused additional bank cutting and erosion. Damages were again primarily agricultural and amounted to \$1,043,000. Tributary damages, not included in the 1964 and January 1965 totals above, were estimated to be \$866,300. Damages prevented by flood fight activities were \$150,000 and \$160,000 in December and January, respectively.

In July 1956, Bridge Creek near Mitchell, Oregon, and Beach Creek near Mt. Vernon, experienced cloudburst floods. The flood on Bridge Creek was the more destructive causing damages that amounted to \$709,000 to buildings, roads, and agricultural land. (24) Other major floods on the John Day River occurred in May 1948, March 1932, and 1894 with flows of 23,000 cfs, 26,800 cfs, and 33,000 (est.) cfs, respectively. (7)



Mt. Vernon, Oregon, on the John Day River, December 1964. (USCE)

Deschutes River Basin

The natural flow of the Deschutes River is extremely constant. Flows of the Deschutes, Metolius, and lower Crooked Rivers are very well sustained by ground water. The constancy of flow is due to the presence of vast underground reservoirs of spongelike pumice soil and lava rock. Ground water percolates out through the porous lava rocks to emerge as large, clear, steady-flowing springs, resulting in the river being as much as 75 percent regulated by nature. Consequently, Deschutes River, itself, has practically no flood history except for the major flood that occurred in December 1964. The peak discharge of that flood near the mouth of the river was 75,500 cfs, almost twice the previous recorded peak of 43,600 cfs, in January 1923. Several irrigation and power reservoirs, notably Prineville, Ochoco, and Lake Billy Chinook, made significant contributions to flood regulation during the critical period of the 1964 flood. (4)

Damages along the main river, amounting to nearly \$2.5 million, were to railroad and highway facilities and included transportation delays. On the tributaries the principal damage areas were below Prineville on Crooked River, near Warm Springs from Shitike Creek, at Kah-Nee-Ta Resort on Warm Springs River, and at Tygh Valley from White River and Tygh Creek.

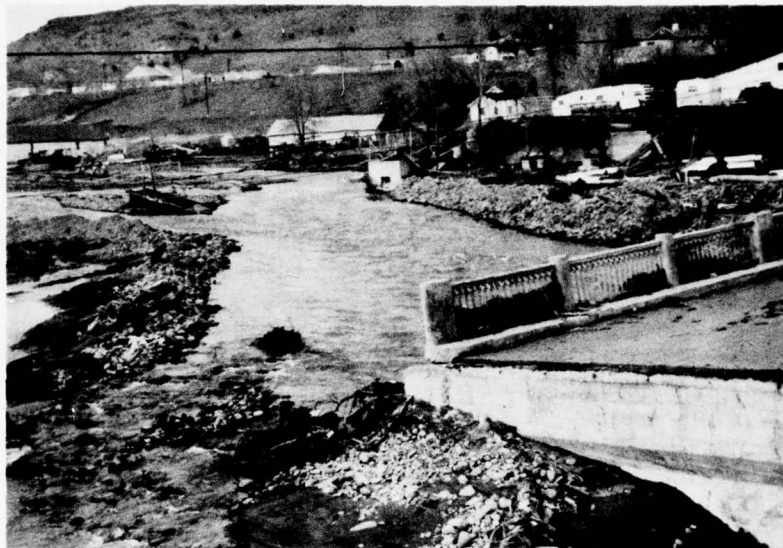
Damages below Prineville were primarily agricultural and were concentrated in Prineville Valley, a relatively flat area about 7 miles long and 1 to 2 miles wide immediately downstream from Prineville. Damages were aggravated by channel capacities inadequate to contain reservoir evacuation releases from Prineville and Ochoco Reservoirs. Flood conditions lasted on some croplands for as long as 2 weeks following the peak of the flood.

At Warm Springs, Shitike Creek caused bank erosion, damaged bridges, and washed out sewage lagoon dikes.

At Kah-Nee-Ta Resort on Warm Springs River, motel units, utilities, and other buildings were severely damaged. Since the December 1964 flood a levee has been built to protect the resort.

At Tygh Valley, White River and Tygh Creek washed out irrigation facilities, and several homes near the streambanks were undermined by bank erosion. Large quantities of silt were deposited on some farmlands.

The total damages from this flood in Deschutes Basin were \$3,979,000; four lives were lost. Reservoirs were estimated to have prevented \$1.3 million damages within the basin and to have contributed to control of damages along lower Columbia River.



Shitike Creek at Warm Springs, Oregon, 1965. (USCE)

Unlike other portions of the basin, the Crooked River sub-basin has a long history of flooding. Since 1890, more than 30 serious floods have been reported in the Prineville area, and flood damages have been reported in the upper valley along a 35-mile reach below Paulina. (7)

Minor Tributaries

The Klickitat and Hood River Basins are relatively minor drainage areas, but damages from the 1964 flood for the two streams were reported as totaling \$1,119,000 and \$3,230,000, respectively. Numerous other minor tributaries and normally dry canyons throughout the subregion sustained damages totaling \$7,185,000, of which almost half were due to disruption of transportation. One life was lost at Spanish Hollow near Biggs, Oregon. (4)

In February 1955, flooding in Zintel Canyon, through Kennewick, Washington, caused \$46,000 in damages. Channel work prevented \$190,000 in damages. Flood fight activities in December 1964 were credited with the prevention of \$10,000 in damages.

In 1947, one life was lost in a flash flood out of Dry Hollow, a normally dry canyon on the eastern outskirts of The Dalles. Also several homes, U. S. Highway 30 and several streets, and a main line railroad were damaged. A flood control study in

1956 found no corrective measures that could be justified at that time.

Summary Table

Flood damages in Subregion 7 were surveyed in detail following the floods of 1948, 1955-56, and 1964-65. Pertinent data from these surveys are presented in table 70. Appendix V, Water Resources, lists floodflows on some other streams.

Table 70 - Flood Damage Survey Data, Subregion 7

Date	Stream Location	Area Flooded (Acres)	Peak Discharge (cfs)	Damages 1/	Damages 1/ Prevented	Remarks
Dec 55	Touchet; Bolles, Wash.	2/	8,410	\$ 15,000	\$ 2,000	Trib. of Walla Walla R.
Dec 64	Walla Walla; Touchet, Wash.	10,800	33,400	2,792,600	1,227,000	
Jan 65	Walla Walla; Touchet, Wash.	2/	15,800	671,000	1,680,000	
Dec 64	Umatilla; Pendleton, Oreg.	450	13,000	828,700	2,358,000	
Jan 65	" Pendleton, Oreg.	12,685	15,500	1,851,400	5,185,000	
Jun 03	Willow Cr., Heppner, Oreg.	2/	36,000 3/	-	-	Cloudburst, 247 lives lost.
Dec 64	" Near mouth	2/	14,700 3/	1,240,000	0	
Jan 65	" Near mouth	2/	1,990 3/	293,000	0	
May 48	John Day; McDonald Ferry, Oreg.	15,000	23,000	373,000		3 lives lost.
Dec 55	" McDonald Ferry, Oreg.	420	22,800	150,000		
May 56	" Service Cr., Oreg.		28,100			
Dec 64	" McDonald Ferry, Oreg.	14,120	42,800	4,998,000	150,000	3 lives lost.
Jan 65	" Service Cr., Oreg.	1,389	38,600	1,043,000	160,000	Plus \$866,300 damages in trib. for 1964-65 floods.
Jul 56	Bridge Cr.; Mitchell, Oreg.	2/	14,400 3/	709,000		Summer cloudburst, trib. of John Day River.
Jul 56	Beech Cr.; Mt. Vernon, Oreg.	50	929 3/	69,000		Summer cloudburst, trib. of John Day River.
Jun 48	Columbia; Trinidad, Wash. 4/	13,192	692,600	4,928,000		
Dec 64	Minor tribs., Kennewick to John Day Dam	2/	-	2,437,000	10,000	Includes Zintel Canyon.
		2/	-	390,000	0	
Feb 55	Zintel Canyon; Kennewick, Wash.	14	360 3/	46,000	190,000	
Dec 64	Deschutes; Moody	2/	75,500	3,979,000	1,300,000	
Dec 64	Hood River, West Fork near Dee, Oreg.	2/	50,000	3,230,000	0	
Dec 64	Klickitat & Little Klickitat, Pitt	2/	31,100	1,119,000	0	
Dec 64	Wind R., Carson	2/	28,500	34,000	0	
Dec 64	White Salmon, Underwood	2/	9,640	66,000	0	
Dec 64	Little White Salmon, Cook	2/	9,560	60,000	0	

1/ Values shown are basin-wide, and are based on development and price levels at time of flood.

2/ Not available.

3/ Estimated value.

4/ Data for reach from Yakima River to Bonneville. Subregion breakdown unavailable.

PRESENT STATUS

Existing Measures

Flood Control Storage

Storage available for flood control in Subregion 7 is shown on table 71. Lake Umatilla behind John Day Dam on the Columbia River has 500,000 acre-feet of storage space allocated for final control of Columbia River floods. This storage is used for other purposes, but is available on a forecast basis when needed during spring floods. Depending on how rapidly the situation develops, all or part of the space may be available for control of a winter flood. Mill Creek Reservoir located about 3 miles upstream from Walla Walla, Washington, has 7,500 acre-feet of storage space used exclusively for flood control. Ochoco Reservoir, on Ochoco Creek, upstream from Prineville in the Deschutes Basin, has 16,500 acre-feet of joint-use storage which is available for flood control during December and January and filled on a forecast basis after January 1 each year. Prineville Reservoir, also upstream from Prineville, but on Crooked River, has 60,000 acre-feet of joint-use storage available for flood control on a scheduled basis and 80,300 acre-feet of surcharge storage. Incidental control of floodwaters has been provided by McKay Reservoir in the Umatilla Basin and Lake Billy Chinook behind Round Butte Dam on Deschutes River. In addition to the



John Day Dam before filling of reservoir. (USCE)

major flood control projects, about 9,100 farm ponds and small reservoirs with a total capacity of 38,000 acre-feet on minor tributary streams afford incidental regulation of floodwaters.

Table 71 - Flood Control Storage Reservoirs, Subregion 7

Reservoir	Inservice Year for Flood Control	Stream	Drainage Area Sq. Mi.	Active Storage 1,000 AF	Exclusive Flood Control Storage 1,000 AF	Joint Storage Available for Flood Control 1,000 AF	Surcharge Storage 1,000 AF
Lake Umatilla	1968	Columbia R.	226,000	500	0	500	0
Mill Creek	1942	Mill Creek	85	7.5	7.3	0	0.8
McKay	1926	McKay Creek	191 1/	73.8	0	(Incidental)	0
Prineville	1961	Crooked R.	2,700	153.0	0	60.0	80.3
Ochoco	1952	Ochoco Creek	300	46.5	0	16.5	6.0
Lake Billy Chinook	2/	Deschutes	7,490	273.9	-	(Incidental)	-
Farm Ponds & Small Reservoirs		Various	-	38	-	(Incidental)	-

1/ McKay Creek at mouth.

2/ Incidental only, does not have flood control function.

Levees and Channels

Five improved channel, levee, and bank protection projects carry small streams through towns. Data on these and other levee and channel projects are shown on table 72. The project on Mill Creek through Walla Walla consists of a concrete-lined channel 2.2 miles long through the center of Walla Walla, Washington. It is designed to carry a standard project flood on Mill Creek as controlled by storage in the Mill Creek Reservoir upstream. The other projects in Milton-Freewater, Dayton, Lowden, and Pendleton consist of improved natural channels with levees and revetments as needed.

The levee at The Dalles was constructed as a part of the Bonneville Project to protect low-lying portions of the city from flooding due to backwater effects of the dam. Later, Interstate 80N was constructed outside the levee. The highway now lies between the levee and the reservoir. The highway embankment is maintained by the Oregon State Highway Department, but the Federal government continues to maintain the levee as the highway fill does not conform to levee standards.



Flood control channel at Walla Walla, Washington. (USCE)

Table 72 - Levee and Channel Projects, Subregion 7

Location	Inservice Year	Stream	Length of Channel Improvement (miles)	Length of Levees (miles)	Revetment (miles)	Design	
						Disch. (cfs)	Freq. (years)
Milton-Freewater, Oreg.	1953	Walla Walla R.	5.7	9.4	9.2	18,600	SPF
Dayton, Wash.	1965	Touchet R.	2.4	3.8	3.8	13,600	1,000
Walla Walla, Wash.	1949	Mill Creek	2.2 ^{1/}	0.3	0.3	5,400	SPF
Lowden, Wash.	1961	Dry Creek	6.7	11.0	0.8	7,000	16
Pendleton, Oreg.	1959	Umatilla R.	4.0	8.7	7.5	28,000	SPF
Stevenson, Wash. & vic.	1962-64	Bonneville Res.	-	-	1.7 ^{2/}	800,000	-
The Dalles, Oreg.	1938	Columbia R.	-	2.4	-	800,000	-
Goldendale, Wash.		Klickitat R. tribs.	7.2				
Various locations on tributary streams:			338	36	83		

^{1/} Rectangular concrete-lined channel.

^{2/} Eight locations between 3 and 36 miles upstream from Bonneville Dam.

A private levee at Bingen, Washington, provides protection for a 100-acre tract used for truck farming. This levee was constructed after the Bonneville Project began operation.

Shoreline erosion along the Bonneville Reservoir resulting from wave action at high reservoir stages was encroaching on private lands not covered by flowage easements. During 1962 to 1964, revetments were constructed at eight locations, seven of which are in Washington, to correct these problems. All construction and maintenance costs are charged to the Bonneville Project.

A small watershed project in and around Goldendale, Washington, consists of 2.6 miles of diversion channel to carry floodwaters of a small tributary around Goldendale, 2.0 miles of stream channel stabilization, and 2.6 miles of storm sewer in Goldendale.

Other work on minor tributaries comprises 35.6 miles of dikes or levees, 337.7 miles of stream channel improvement, 33.5 miles of stream channel stabilization, and 49.2 miles of stream-bank protection.

Land Treatment

The watershed protection practices applied to croplands in this subregion which are most effective in reducing erosion and sedimentation and assisting in reduction of flood damages include conservation cropping systems on 928,000 acres, crop residue use on 740,000 acres, stubble mulch on 570,000 acres, and 866 miles of diversions and terraces. More than 850,000 acres of cropland have been adequately treated.

On forest lands, 81,000 acres have been treated to reduce sediment and floodflows by seeding of badly eroded areas and stabilization of gullies with plugs and sediment traps. More than 3,000 miles of roads and trails have been rehabilitated as a means of controlling erosion.

Rangeland practices of particular significance in reduction of erosion and sediment and aiding in reduced flow include seeding 232,800 acres to grass, controlling brush on 224,600 acres, and reducing excessive grazing on 2,100,000 acres.

It is estimated that the soils of Subregion 7 have a water holding capacity of at least 9.55 million acre-feet, or an average of 6.09 inches over the entire watershed. With proper land treatment and under ideal climatic conditions, much of this storage would fill before a major flood developed. Additional information on land treatment is included in Appendix VIII.

Flood Plain Regulation Program

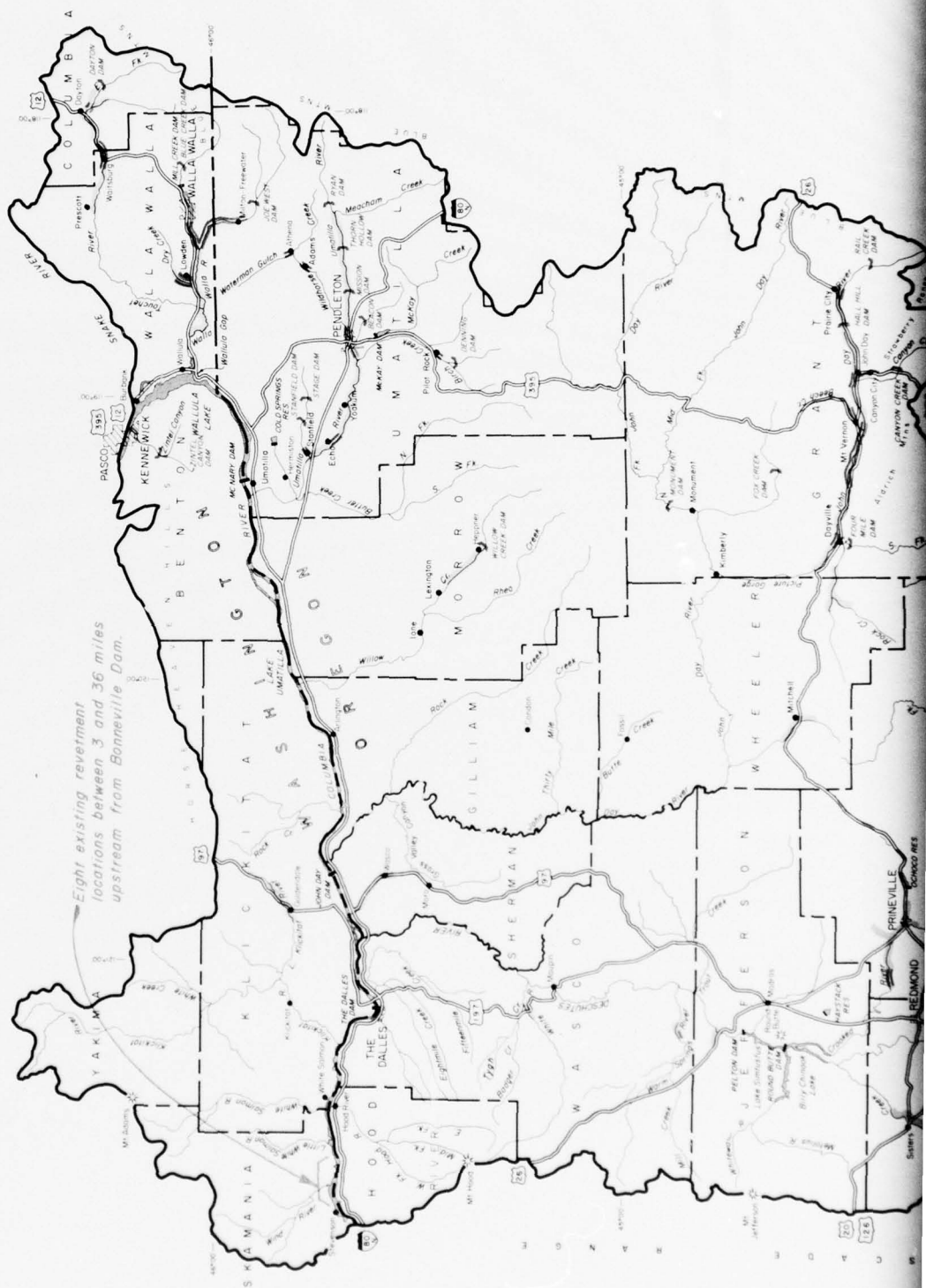
Flood plain information reports covering approximately 8 miles along the Umatilla River above Pendleton, several Umatilla River tributaries in and near Pendleton, and Canyon Creek through Canyon City in the John Day Basin have been prepared. Grant County planning officials have been furnished flood plain maps showing the extent of the December 1964 and January 1965 floods on John Day River from Prairie City, downstream to the Grant-Wheeler County line. In Washington, a flood plain information report covering Walla Walla River tributaries in and near the city of Walla Walla has been prepared. A similar report has been requested to cover the Walla Walla River from the Oregon-Washington State line to McNary Reservoir. Flood information has been furnished to other city and county officials on specific locations. The General Services Administration has been apprised of flood hazards at various Federal buildings in the subregion and the Federal Housing Administration has been given flood information on a proposed subdivision in Kennewick.

Flood Forecasting and Emergency Operations

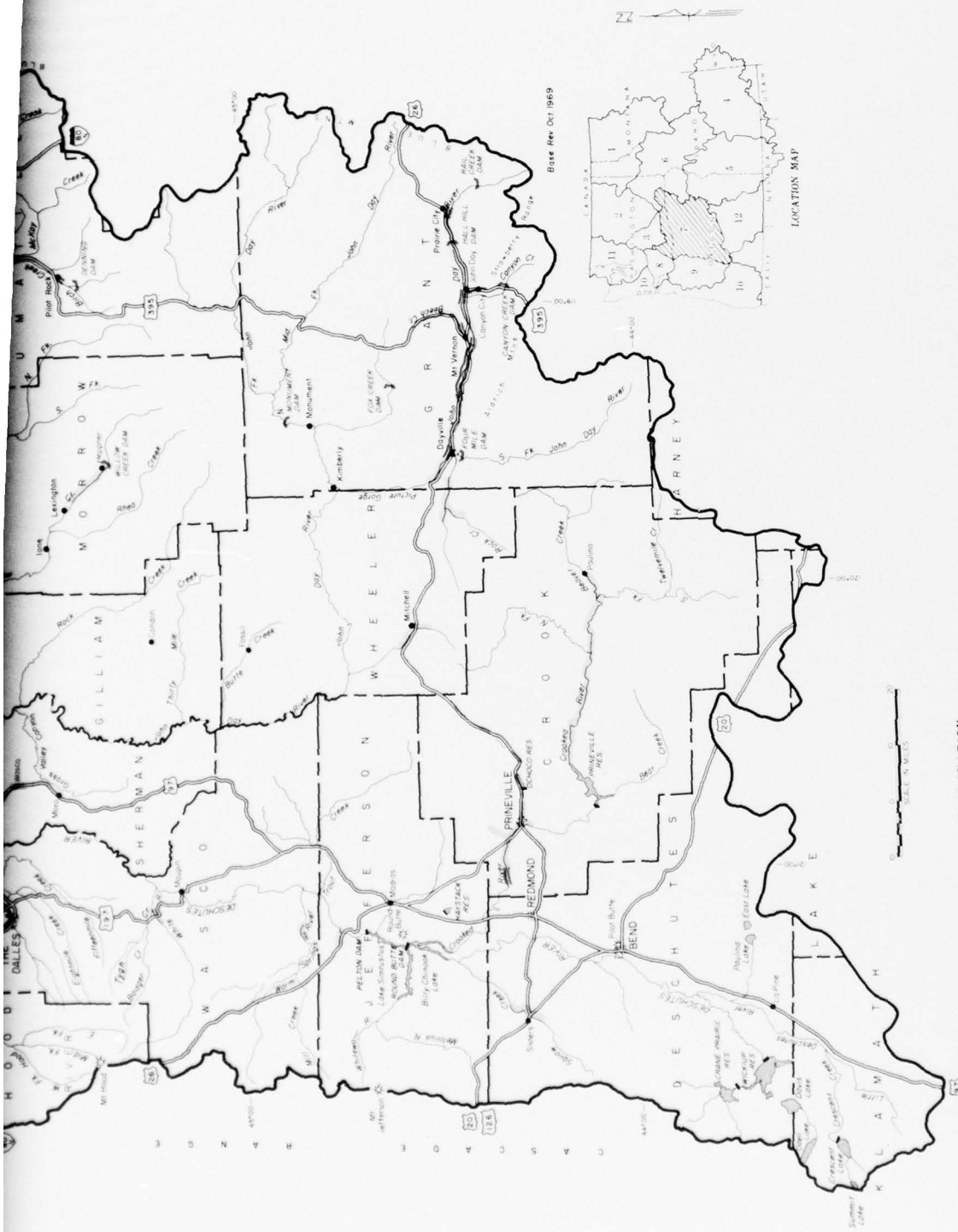
Streamflow forecasts including flood warnings are made by the Cooperative Columbia River Forecasting Unit for the following seven locations in Subregion 7:

<u>Forecast Point</u>	<u>River</u>
Joe West Bridge, Oregon	Walla Walla
McNary Reservoir Inflow, Washington	Columbia
Pendleton, Oregon	Umatilla
Service Creek, Oregon	John Day
Moody, Oregon	Deschutes
The Dalles Reservoir Inflow, Oregon	Columbia
Bonneville Reservoir Inflow, Oregon	Columbia

In addition, flood forecasts are made for other locations on tributary streams during emergencies. The flood forecasts are disseminated by the National Weather Service office in Portland to various local offices such as the county civil defense, news media, and county and city agencies. The city of Walla Walla has the only flash flood warning system that is operated formally. The operator of the city water intake, on the headwaters of Mill Creek, has the responsibility of notifying city officials whenever high flows appear imminent. Flood emergency operations throughout the subregion, particularly in Walla Walla, John Day, and Umatilla River Basins and consisting of sandbagging, raising, and strengthening levees, and temporary evacuation of people,



Eight existing revetment
locations between 3 and 36 miles
upstream from Bonneville Dam.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY
**EXISTING & POTENTIAL
FLOOD CONTROL FACILITIES**
MID COLUMBIA SUBREGION 7

1970

FIGURE 18

personal belongings, and livestock have prevented damages throughout the subregion. Flood fight organizations are formed at the time the emergencies arise and generally include the National Guard and the Corps of Engineers as well as the local people.

Accomplishments

Storage

The 500,000 acre-feet of active storage in Lake Umatilla provides for final control of floods on the lower Columbia River to predetermined levels, on a day-to-day basis, see table 82. The Mill Creek diversion dam and offstream storage reservoir reduces a standard project flood at Walla Walla, Washington, from 11,300 cfs to 5,400 cfs. McKay Reservoir has been effective in reducing flood damages in the lower reaches of McKay Creek. It is estimated that incidental regulation of floodflows at McKay Dam reduces average annual damages from \$63,600 to \$18,300. Ochoco and Prineville Reservoirs reduce average annual damages in the Crooked River subbasin by \$127,000 at 1965 prices and development. Ochoco Reservoir normally controls a 50-year flood to within bank flows in Ochoco Creek through Prineville. However, an intense rain flood late in the season, such as occurred in May 1956 when much of the joint storage space had been filled for conservation use, could produce discharges in excess of channel capacities and flood portions of Prineville.



Prineville Reservoir. (USCE)

Levees and Channels

Improved channel and levee projects reduce flood damages in the towns of Milton-Freewater, Dayton, and Walla Walla and in the rural area of Lower Dry Creek in Walla Walla River Basin and in and near the town of Pendleton in Umatilla River Basin.

Comprehensive Watershed Projects

Comprehensive treatment programs on two watersheds have reduced average annual damages on 1,000 acres subject to flooding from \$26,000 to \$4,000.

Flood Forecasting and Emergency Operations

Flood emergency operations have prevented a considerable amount of damages to properties in many of the communities located on tributary streams. Communities where damages have been prevented by flood fight operations include Waitsburg and Milton-Freewater in the Walla Walla River Basin; Canyon City, Mt. Vernon, John Day, Prairie City, and Dayville in the John Day River Basin; and Pendleton, Pilot Rock, Echo, and Stanfield in the Umatilla River Basin. The best information about the monetary value of damages prevented by flood fight operations is that gathered after both the December 1964 and January 1965 floods.

The December 1964 flood caused damages estimated at \$12,296,300 in the portion of Subregion 7 upstream from John Day Dam and \$650,000 damages prevented were attributed to emergency operations. (23) For the same area the January 1965 flood caused damages estimated at \$4,248,500 and \$950,000 damages were prevented by emergency operations. It is interesting to note that the January flood damages were about 35 percent of the December damages but that more damages were prevented in January. Several factors contributed to the more effective operation in January. The region had been declared a disaster area and the Office of Emergency Planning was administering disaster relief. In many areas repair crews were in the field at the onset of the flooding and were able to take immediate emergency action. People were more alert to flood hazards, and in addition, procedures for effective coordination among agencies had become more clearly understood.

The January 1965 flood was much less severe in the portion of the subregion downstream from John Day Dam, and damages during the two floods were not separated. Total damages in that area were estimated to be \$13,237,000, and damages prevented by emergency operations about \$300,000.

Summary of Accomplishments

Flood control projects, both storage and channel, reduce average annual damages from \$1,506,000 to \$834,700 in areas protected by projects. Data on acreages in the flood plains and damages without and with flood control projects are listed in table 73.

Table 73 - Project Accomplishments, Subregion 7

Stream Basin	Station	Acres in Flood Plain		Ave. Ann. Damages	
		w/o Proj.	w/Proj.	w/o Proj.	w/Proj.
Columbia R.	The Dalles, Oreg.	1/	Nil	1/	Nil
Walla Walla R.	Above Mill Cr.	8,250	2,730	\$ 179,000	\$159,000
Touchet R.	Below Patit Cr.	3,900	3,300	133,700	112,900
Mill Cr.	Walla Walla, Wash.	3,300	1,750	318,000	21,000
Dry Cr.	Lowden, Wash.	1/	1/	89,000	14,000
Umatilla R.	Pendleton, Oreg.	29,400	28,300	272,000	237,000
McKay Cr.	McKay Dam	200	200	63,600	18,300
Willow Cr.	Heppner, Oreg.	1,900	1,900	118,200	118,200
John Day R.	Below Canyon Cr.	16,500	16,500	178,700	127,500
Crooked R.	Below Prineville & Ochoco R.	1/	1/	153,800	26,800
Two watersheds		1,000	0	26,000	4,000
Total				\$1,532,000	\$838,700

1/ Not available.

Remaining Flood Problems

Slack water extends throughout the reach of the Columbia River in Subregion 7. Because the Federal government has flowage easements along the periphery of the reservoirs and because levees were constructed in the Tri-Cities area and at The Dalles as part of the projects, flood damages on the Columbia River are insignificant except during extremely rare, catastrophic floods. Flood problems exist in the principal tributary basins on the Walla Walla, Umatilla, John Day, and Deschutes Rivers and Willow Creek. Data on acreages in tributary flood plains are listed in table 74. Average annual damages are listed in table 75. Flood problems are discussed subsequently by specific streams.

Walla Walla River Basin

The area along the Walla Walla River extending about 10 miles from the lower limits of the existing Milton-Freewater flood control project downstream to the mouth of Mill Creek in Washington is subject to inundation damages. This area includes extensive, highly developed, agricultural lands. Damages in other areas along the Walla Walla River are generally confined to erosion or inundation of cultivated and pasturelands and erosion of bridge

Table 74 - Areas Flooded, Subregion 7^{1/}

Stream	Station	Minor Floods		Major Floods	
		Acreage in Flood Plain		Acreage in Flood Plain	
		Urban	Rural	Urban	Rural
Walla Walla R.	Touchet, Wn.	10	470	68	1,370
Touchet R.	Below Patit Cr.	460	640	920	1,300
Mill Cr.	Walla Walla, Wn.	10	140	70	1,100
Dry Cr.	Lowden, Wn.	2/	2/	2/	2/
Umatilla R.	Yoakum, Ore.	67	5,040	435	17,500
McKay Cr. 3/	McKay Dam				
Willow Cr.	Heppner, Ore.	150	750	175	900
John Day R.	Below Canyon Cr.	500	5,600	800	11,250
Deschutes River	Pelton Dam	2/	2/	2/	2/
Crooked R. 4/	at Forest Crossing	100	1,000	200	6,840
Squaw Creek	Sisters	2/	2/	2/	2/
White River	Tygh Valley	2/	2/	2/	2/
Hood River	Mouth	2/	2/	2/	2/
Hood River East Fork	Parkdale	2/	2/	2/	2/
Klickitat River	Mouth	2/	2/	2/	2/
Little Klickitat	Goldendale	2/	2/	2/	2/
Fifteenmile Creek	Mouth	2/	2/	2/	2/
Spanish Hollow	Wasco	2/	2/	2/	2/
Zintel Canyon	Kennewick	17	0	167	0

1/ With 1970 flood control facilities and 1967 prices and economic development.

2/ Not available.

3/ McKay Reservoir provides flood protection for all but major floods.

4/ Including Ochoco Creek below Ochoco Reservoir.

approaches. The flood control projects on Mill Creek provide substantial flood protection through the town of Walla Walla, but farmhouses, buildings, and agricultural lands along the lower 5-mile reach of the stream are subject to flooding. A reach along the Touchet River that extends from just below Dayton to the vicinity of Prescott, including a section of the town of Waitsburg and highly productive agricultural lands, is subject to inundation and bank erosion. In addition, areas above Dayton and on the lower Touchet River are subject to flood damage. A flood control project at Dayton affords that community flood protection. Portions of the Prescott and Touchet communities are within the flood plain of the larger floods. Damages occur in rural areas along the lower 7 miles of Dry Creek. The existing channel project on this reach protects against only the smaller more frequent floods.

Umatilla River Basin

Flood runoff from the Umatilla River and tributaries, principally Wildhorse Creek, Birch Creek, and Butter Creek, causes annual losses in the form of erosion, inundation of developments and crops, and wash of land by overflow. Because of topography, a large portion of the economic development is in the bottom lands of the main stream and tributaries. The valley above Pendleton is narrow with a limited degree of agricultural development and is subject to frequent overbank flooding. Existing levees through Pendleton provide the area a high degree of protection. Below Pendleton, major floods inundate a large part of the town of Echo and scattered dwellings on the outskirts of Umatilla, destroy or

damage irrigation headworks, and generally disrupt irrigation facilities throughout the valley. The Union Pacific Railroad and secondary highways and farm roads along the river from Meacham Creek to the mouth are subject to inundation at many points. With the exception of lower Butter Creek, tributary streams have steep gradients and relatively narrow flood plains and all are subjected to bank erosion and overflows. In addition to agricultural and transportation improvements located in the flood plains of the tributaries, floods damage the towns of Adams, Athena, Pilot Rock, and Stanfield.

Willow Creek Basin

The flood plain of Willow Creek generally extends the width of the narrow valley, which varies from a few hundred feet to about three-quarters of a mile. Valleys of the tributaries are narrower; generally less than one-quarter of a mile wide. Most of the valley areas are used for the production of forage crops, principally alfalfa, and the pasturing and winter feeding of livestock. The urban developments of Heppner, the small towns of Lexington and Lone, and many farm buildings, warehouses, and other improvements are situated in these narrow valleys. A railroad, a state highway, and county roads are located in the valley bottom. The largest damage potential is in the Heppner area from thunderstorm cloudburst flooding. Since 1903, Heppner has redeveloped in its former preflood location on the canyon floor; consequently, inhabitants of the town are endangered by the potential of a repetition of the 1903 disaster. Cloudburst floods arise and travel downstream so rapidly that loss of life is a constant threat throughout the basin.

John Day River Basin

Flood damages occur in the extensively cultivated upper valley of the John Day Basin, which is a reach of the main river from Prairie City to Picture Gorge, a few miles downstream from Dayville. Land use in the flood plain is chiefly for hay and pasture crops, which are an integral part of the cattle industry of the basin. Five communities in the upper valley - Dayville, Mt. Vernon, John Day, Canyon City, and Prairie City - are subject to flood damage. Damages are relatively minor from Picture Gorge to the confluence with the Columbia River. Tributaries of the main river - particularly Canyon Creek, Beech Creek, the North and South Forks John Day River, and Rock Creek, have areas of substantial flood damage. Considerable bank erosion has resulted in loss of much land. Extensive damages to roads and bridges are caused by inundation and washouts by both main and secondary

streams. Numerous washouts, slides, and debris deposits are caused by water rushing out of small, normally dry, sidehill gullies.

Deschutes River Basin

Flood damages in the Deschutes River Basin occur in the Crooked River Valley in the vicinity of Prineville, at Warm Springs on Shitike Creek, at Tygh Valley on Tygh Creek, and the White River, and during extreme floods to the railroad along the lower main river. At Warm Springs and Tygh Valley, floodwaters are uncontrolled and only minor local protective measures have been taken. At Prineville most flood flows in the Crooked River and Ochoco Creek are controlled in the Prineville and Ochoco Reservoirs. Remaining damages result from floods in excess of the capacity of the Ochoco Reservoir, from uncontrolled flows in McKay Creek, a minor tributary entering the Crooked River a few miles downstream from Prineville, and from prolonged ponding on lands along the Crooked River flooded by evacuation releases that exceed the capacity of the river channel. Flows on the main Deschutes River are normally very uniform, and infrequent larger flows may be further regulated by Lake Billy Chinook although such regulation cannot be assured. The only recorded damages occurred during the December 1964 flood. (4) However, development throughout the basin is increasing rapidly and damages in the future may become more significant.

Looking south at the Crooked River downstream from Prineville, Oregon. Head of the Crooked River Gorge at far right. (USCE)



Minor Tributaries and Upland Areas

In the upper reaches of Hood River watershed, floods occur when terminal moraine lakes at the foot of glaciers break and release the impounded water. The floods and accompanying mudflows damage timber stands; wash out roads and bridges; deposit silt, gravel, and boulders; and inflict serious damages to irrigation works. Approximately 600 acres of agricultural land on Middle Fork and 200 acres on West Fork Hood River are flooded frequently.

Zintel Canyon, a normally dry watercourse, drains about 27 square miles of the northern slopes of Horse Heaven Hills and flows through the residential and business districts of Kennewick, Washington to Columbia River. Flooding occurs infrequently, but average annual damages are \$73,000.

A minor flood problem exists along the northern edge of the city of Goldendale, Washington, where floods in Little Klickitat River inundate a few streets, a stockyard and barn, a trailer park, two residences, and the city sewage treatment plant.

Areas flooded by other minor tributaries and in upland areas comprise more than 86,000 acres of cropland, 10,000 acres of forest land, 24,000 acres of rangeland, and 3,400 acres of urban land. Average annual damages on these lands amount to \$2,322,000 rural and \$170,000 urban.



Streambank Erosion Summary

Throughout much of the Subregion 7, streambanks are vertical in light, easily eroded soil and without vegetative cover. Banks are therefore subject to considerable undercutting and sloughing. Serious erosion occurs on an estimated 6,400 miles of streambank and the annual land loss is estimated to be 7,700 acres. Essentially all of the eroded material remains in the subregion and most within the individual stream basins. Present average annual damages including land loss, sedimentation, adverse effects on aquatic life, recreation, and so forth, are estimated to be \$1,144,000 of which less than 7 percent is urban and the balance rural.

PROJECTIONS AND NEEDS

Economic Trends

The population of Subregion 7 is expected to grow at a slower rate than that of the region as a whole. In 1965, the population of the subregion was 210,500, a density of seven persons per square mile. Population projections are for 251,400 in 1980, 321,800 in 2000, and 404,400 in 2020. This represents a growth rate of about 1.2 percent annually. Most of the projected population growth is expected to take place in the larger communities and the population in unincorporated areas to remain about at the present level or declining slowly. The most rapid growth should occur at the larger cities of Kennewick, Walla Walla, Pendleton, Bend, and The Dalles, which act as market and service centers. A lower rate of growth, about equal to the 1.2 percent per year projected for the subregion as a whole, is expected to occur at intermediate-sized cities such as Hood River, Redmond, Prineville, Goldendale, Hermiston, Milton-Freewater, and Dayton. Population changes at smaller incorporated places are likely to be erratic, ranging from growth at about the subregion's average down to stagnation or decline.

Agricultural production is expected to increase, but employment in agriculture is projected to decline slightly because of more efficient use of labor and greater capital investment per worker. The growth in employment underlying the projected population increase will take place in the following industries: primary metals (aluminum and magnesium), pulp and paper, miscellaneous manufacturing, and service industries.

Land Use Trends in the Flood Plain

Little change is expected in cropping practices in most flood plain areas. However, some areas in the Umatilla and Walla Walla basins and in the Crooked River subbasin are irrigated but have inadequate water supplies. If these areas are provided additional water, they will be cropped more intensively and potential flood damages will increase. Urban development is expected to expand into the flood plains adjacent to Walla Walla, Pendleton, Kennewick, and Prineville and to a minor extent at some other cities. The estimates of future flood damages allow for this expansion.

Flood Damage Projections

Present and projected flood damages in Subregion 7 are shown in table 75. Estimates of future damage levels are based on economic projections prepared for Appendix VI, "Economic Base and Projections." The effects of existing (1970) flood control works are reflected in the projected damages, but effects of future measures, either structural or nonstructural, are not.

The growth factors for rural damages were developed from yield projections for specific crops presently raised in the flood plains and, for nonagricultural damages, from the per-capita income growth factor for the subregion. The projections of urban damages were based on the expected growth at each specific area. Damages in the Kennewick and Pendleton areas were projected at the growth rate for total personal income in the subregion. In other areas, the growth rates were adjusted downward to reflect slower anticipated development in flood plain areas.

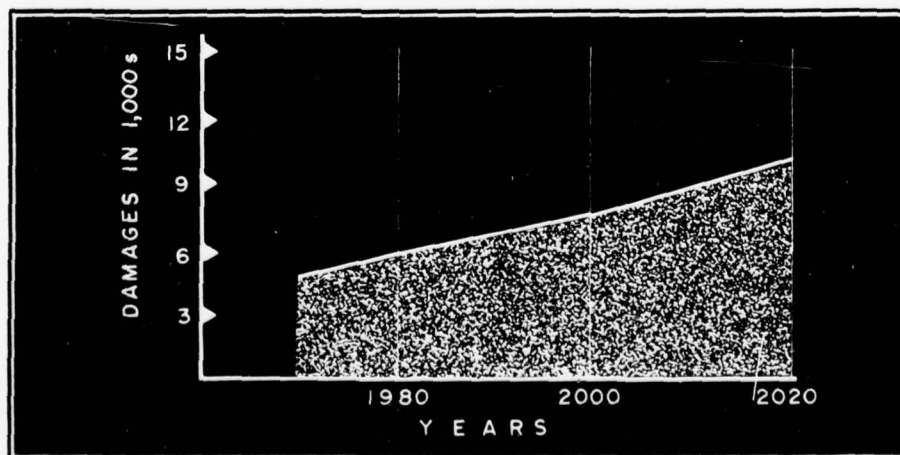


Figure 19. Projected Average Annual Flood Damages, Subregion 7.

Table 75 - Distribution of Flood Damages, Current and Projected,
Subregion 7

Stream Basin	Average Annual Flood Damage in \$1,000, 1967 Price Levels					
	With 1967			With Projected		
	Economic Development			Economic Development		
	Rural	Urban 1/	Total	1980	2000	2020
Walla Walla R.	\$ 128	\$ 31	\$ 159	\$ 210	\$ 298	\$ 437
Mill Cr.	15	6	21	30	49	79
Dry Cr.	14	0	14	18	23	28
Touchet R.	70	43	113	157	247	387
Umatilla R.	192	45	237	357	468	679
McKay Cr.	16	3	19	27	47	80
Willow Cr.	65	53	118	175	305	525
John Day R.	111	16	127	165	232	313
Deschutes R.	22	0	22	29	42	63
Crooked R.	5	29	34	45	72	117
Klickitat R.	9	22	31	41	65	104
Hood R.	75	0	75	95	142	212
Other streams	26	71	97	159	333	694
Streambank erosion, all basins	1,068	76	1,144	1,186	1,262	1,416
Minor tributaries	2,322	170	2,492	3,115	4,062	4,884
Total	\$4,138	\$565	\$4,703	\$5,809	\$7,647	\$10,018

1/ Includes transportation, commercial, and industrial.

Summary of Flood-Control Needs

The present-day average annual flood damages of \$4,703,000 are 88 percent rural and 12 percent urban. Agricultural damages are projected to increase approximately 200 percent by the year 2020 through increases in agricultural investment and productivity and by more intensified land use. Urban damages are projected to increase by approximately 300 percent.

The flood problems at Heppner, Oregon, and Kennewick, Washington, present the most immediate concern within the subregion. Measures for solution of these problems have been authorized for construction by the Corps of Engineers and local interests are ready to assume their portions of the work. However, Federal construction funds have not been appropriated. Damages in most other parts of the subregion are more widely spread and it is problematical whether problems in any specific area will become sufficiently acute prior to 2020 as to warrant single purpose flood control measures. However, there are several areas as discussed under "Measures to Satisfy Needs" which have flood problems which would be substantially reduced by multiple-purpose storage projects.

The annual loss of land due to streambank erosion is not expected to change except as influenced by corrective measures. The value of land loss and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being

primarily based on removal costs, will remain relatively constant. Future annual damages will amount to \$1,186,000 in 1980, \$1,262,000 in 2020, and \$1,416,000 in 2020.

MEASURES TO SATISFY NEEDS

Measures to alleviate flood damages include storage, channel and levee works, nonstructural measures, and combinations thereof. Storage capacities needed in specific areas to control floods of standard project flood magnitude to nondamaging stages are listed in table 76. These storage volumes were estimated without considering economic feasibility or availability of satisfactory storage sites although, as shown in table 77, sites are available which would physically meet many of the storage needs.

Table 76 - Additional Storage Needed to Eliminate Flood Damages Caused by Major Streams, Subregion 7

Stream	Principal Flood Problem Area	Bankfull Capacity (cfs)	Upstream Storage ^{1/} Needed for Flood Control (ac.-ft.)
Zintel Canyon	Kennewick	200	5,700
Walla Walla R.	Milton-Freewater to Mill Cr.	3,500	27,000
Touchet R.	Dayton to Waitsburg	3,000	82,000
Mill Creek	Lower 5 miles	1,500	18,000
Dry Creek	Lower 7 miles	3,000	46,000
Umatilla R.	Pendleton to Echo	6,500	232,000 ^{2/}
McKay Creek	Pendleton	1,000	43,000
Willow Creek	Heppner	1,500	14,000
John Day R.	Prairie City to Picture Gorge	2,500	178,000
Klickitat	Goldendale		50,000

^{1/} The storage needed is that required, together with existing storage to control a flood of standard project magnitude to nondamaging stages. Storage needed does not consider availability of sites or economic feasibility.

^{2/} Includes the 43,000 acre-feet needed on McKay Creek.

Nonstructural measures including flood plain zoning and forecasting could help reduce future damages on most of the streams even though many of the flood plain areas are expected to continue in agricultural usage. In the rural areas future farm buildings can be located to minimize flood damages. Roads, bridges, and utilities can be suitably flood proofed. With adequate warnings, livestock and mobile equipment could be moved to safe locations.

Basin Discussions

Flood control measures that could reduce damages in specific problem areas are discussed subsequently.

Walla Walla River Basin

A multiple-purpose reservoir on Walla Walla River at the Joe West Damsite below the confluence of North and South Forks and about 2 miles upstream from Milton-Freewater, Oregon, could effectively control floods on Walla Walla River near Milton-Freewater, Oregon, and significantly reduce floods farther downstream. The 10-mile reach from the downstream end of the existing Milton-Freewater project to the mouth of Mill Creek is the area with most concentrated flood damages along Walla Walla River. Present average annual damages in this area total about \$23,000. A local protection project that would protect from flows that have over 100-year exceedence frequency is estimated to cost about \$775,000. Based on expected increase in damages in this reach, local flood works may become economic about 1980. Flood plain zoning regulations could prevent growth of damage potential in the Walla Walla Basin along the 10-mile reach of Walla Walla River below Milton-Freewater, the lower 5-mile reach of Mill Creek, and along Touchet River near Waitsburg.

Mill Creek A reservoir on Mill Creek at the Blue Creek Damsite, immediately below the confluence of Mill Creek and Blue Creek and about 9 miles upstream from the city of Walla Walla, Washington, would prevent about 90 percent of the present average annual damages on Mill Creek. The reservoir would enhance the protection afforded by existing projects and extend protection to areas upstream and downstream. A local flood control project along the 5-mile reach below the existing channel project is an alternative means of preventing damages in that rich agricultural area. However, projected developments indicate that such work would not be feasible until after 1980.

Touchet River A multiple-purpose reservoir on the East Fork of the Touchet River at the Dayton Damsite, about 5 miles above Dayton, Washington, which would provide 15,000 acre-feet of storage space for flood control, would reduce present average annual damages along Touchet River by about 25 percent. Supplementing the flood control by storage on Touchet River by a channel levee project, would protect the town of Waitsburg and surrounding agricultural lands from flows up to 145-year exceedence frequency (unregulated) magnitude. Such work, costing about \$700,000, would reduce damages along Touchet River by another 25 percent.

Table 77 - Potential Storage Sites, Subregion 7 ^{1/}

Basin and Stream	Damsite	River Mile	Potential Storage (acre-feet)	Discussion
Zintel Canyon	Zintel Canyon	4.1	2,200	About 67% of the drainage area is above the damsite. Storage sites are not available for control of the remaining drainage area.
Walla Walla River Basin Walla Walla River	Joe West	56.7	118,000	Could afford effective control of floods near Milton-Freewater, Oregon, and significant reduction of floods farther downstream.
Touchet River	Dayton	68.0	52,600	Estimated to reduce damages in Touchet River Basin by 25%.
Mill Creek	Blue Creek	19.6	65,000	Operation could be coordinated with the existing flood control project to provide a high degree of protection below the existing project. Storage development in Walla Walla River Basin could also benefit irrigation, water quality, water supply, and recreation.
Umatilla River Basin Umatilla River	Mission	61.2	142,000	Would require costly railroad relocation.
Umatilla River	Thornhollow	74.5	58,000	Would require costly railroad relocation.
Umatilla River	Ryan	80	143,000	Could reduce flooding in vicinity of Pendleton.
Tutuilla Creek	Beacon	5.6	107,000	Could control floods on Patawa and Tutuilla Creeks and with a connecting tunnel, could impound portion of McKay Creek flows.
Birch Creek	Denning	25.4	20,000	Being located above the town of Pilot Rock, Oreg., Denning Reservoir could reduce the flood threat to that community.
Stage Gulch	Stanfield	6.0	20,000	Stanfield Reservoir could reduce flood flows at Stanfield, Oregon.
Stage Gulch	Stage	13.1	70,000	Stage Reservoir would control only a small portion of the drainage area above Stanfield, Oreg. Storage development in Umatilla River Basin could also benefit recreation, water quality, water supply and irrigation.
Willow Creek Basin Willow Creek	Willow Cr.	52.5	11,500	This size of reservoir would be capable of storing a flood such as occurred in 1903 and took 247 lives in the community of Heppner, Oregon. Storage would also benefit irrigation, water quality, water supply, and recreation.
John Day River Basin John Day River	Fourmile	4.6	25,000	Could substantially reduce damage on John Day R.
John Day River	Hall Hill	260.0	45,000	Could substantially reduce damage on John Day R.
John Day River	Rail Creek	272.0	13,000	Could substantially reduce damage on John Day R.
Canyon Creek	Canyon Cr.	12.8	41,500	Could reduce damages at Canyon City and along main stream below town of John Day.
N. F. John Day River	Monument	22.0	250,000	Could substantially reduce damages on North Fk.
Fox Creek	Fox Creek	0.5	11,000	Minor flood control on Fox Creek and along North Fork below town of Monument. Storage in John Day Basin could also benefit irrigation, power, water supply, and recreation.

^{1/} This information is furnished for possible use in plan formulation and includes the total storage capability at many sites. The amount that would be usable for flood control would in many cases be considerably less.

Dry Creek The most practical structural means of reducing the remaining flood damages on Dry Creek appears to be an enlargement in the capacity of the existing channel project.

Umatilla River Basin

A multiple-purpose reservoir on the upper Umatilla River at the Ryan site, about 26 miles above Pendleton and 1 mile upstream from the mouth of Meacham Creek, could effect significant reductions in downstream damages; however, even with a high degree of control at the Ryan damsite, flows from Meacham, Wildhorse, Birch, Butter, and other smaller creeks could cause overbank flooding on the Umatilla River below Pendleton. A channel and levee project on the 5-mile reach of Umatilla River upstream from Echo would protect the town of Echo and much of the fertile irrigated lands in the area. Such a project designed to protect the agricultural lands and the town from floods up to 55 years and 100 years of exceedence frequency magnitude, respectively, is estimated to cost about \$1,000,000.



Umatilla River at Echo, Oregon, January 1965. (USCE)

Flood plain regulations could prevent development that appears imminent along the Umatilla River immediately upstream from Pendleton. Regulations would also be appropriate for the reach upstream from Echo although development in that area is less likely to occur.

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Tutuilla and McKay Creeks A multiple-purpose reservoir at Beacon Damsite on Tutuilla Creek, with a diversion tunnel from the existing McKay Reservoir to Tutuilla Creek would almost eliminate flooding on Patawa and Tutuilla Creeks at Pendleton and enhance the flood control on McKay Creek. Flood plain regulations are urgently needed for the area along the lower reaches of McKay Creek where rapid urban development is occurring.

Birch Creek Multiple-purpose storage development on the East Fork of Birch Creek at the Denning Damsite would afford incidental floodflow regulation for the town of Pilot Rock and agricultural lands downstream. The problem at Pilot Rock also could be solved by a channel project, but this would not help the agricultural lands downstream.

Stage Gulch A dam at the Stanfield site in lower Stage Gulch Canyon could significantly reduce floodflows at Stanfield. Stanfield also could be protected by a channel project. Future damages in the Stanfield area could be minimized by flood plain zoning.

Wildhorse Creek A combination of channel projects and flood plain zoning could reduce damages at the towns of Adams and Athena.

Willow Creek

Congress has authorized construction of a multiple-purpose dam and reservoir on Willow Creek above the town of Heppner, Oregon, and an improved channel through the town. (27) The reservoir would have a total capacity of 11,500 acre-feet and the channel, a capacity of 1,500 cfs. The reservoir would store a flood such as occurred in 1903. The combination storage and channel project would prevent an estimated 86 percent of the total damages in the basin. Nonstructural measures could be partially effective in limiting future growth of flood damage potential in the Heppner area. However, flood plain zoning is not considered to be an adequate solution to the flood problems because of the extensive development that now exists in the flood plain.

John Day River Basin

Storage Approximately 178,000 acre-feet of additional storage including 28,000 acre-feet on both Canyon and Beech Creeks would be needed to control a flood of standard project flood magnitude on the main river from Prairie City to Picture Gorge. On

the North Fork John Day River about 550,000 acre-feet of additional storage above Monument would control a flood of standard project magnitude and prevent most of the damages on that stream. However, the total benefits available for flood control on the North Fork would justify only a small portion of the storage cost.

Channel and Levee Projects Construction of additional channel and levee works on the main stem in the vicinity of Mt. Vernon, is being investigated by the Corps of Engineers. Preliminary data indicate that a project beginning 1.5 miles below Mt. Vernon and extending about 8 miles downstream would protect from floods up to 50-year exceedence frequency magnitude and cost approximately \$400,000. Other channel improvement and levee works could protect the small towns of Dayville, John Day, Canyon City, Mt. Vernon, and Prairie City.

Nonstructural Measures Most of the economic growth in the basin is expected to occur in the vicinity of the town of John Day. Although the town is protected from floods along John Day River and lower Canyon Creek, development could occur in the Canyon Creek flood plain between John Day and Canyon City. Flood plain regulations should be used in that area to minimize the growth of flood damages.

Deschutes Basin

Storage Flood problems in the Deschutes Basin are generally not amenable to relief by further storage. The principal damages along the main river occur to the Burlington-Northern Railroad, which follows the river from the mouth to about mile 85. The railroad sustained substantial damages in the 1964 flood even though the river was controlled at Round Butte Dam, river mile 111. Areas of critical flood damages in the Crooked River Sub-basin are presently protected by storage in Ochoco and Prineville Reservoirs except that additional channel capacity is needed to allow evacuation of stored floodwaters. Damages along other tributaries occur generally in isolated areas, and each would require an individual storage project. Ochoco Reservoir only protects to 50-year flood. A study is needed to determine if more protection is justified.

Channels and Levees Channel improvements, bypassing of meander bends, and levee construction along Crooked River to prevent flooding during reservoir evacuation following floods and protect against 25-year floods are estimated to cost about \$750,000. Another possible solution would be channel improvement where the river cuts through a lava flow and enters the lower canyon immediately downstream from the flood reach. This work

would cost about \$250,000, but the degree of relief it would provide has not been determined.

Minor Tributaries and Upland Areas

Structural measures are not considered practicable for prevention of damages by floods and mud flows in the upper reaches of Hood River and tributaries. Zoning and keeping residents apprised of the hazards are applicable, but extensive developments are not anticipated so results would be nominal.

The best means of protecting the city of Kennewick, Washington from high flows out of Zintel Canyon appears to be a combination project consisting of a detention reservoir and a flood conduit and channel through the city. Such a project, designed to be fully effective for floods up to 200-year frequency, is estimated to cost about \$2,000,000. The project would reduce present average annual damages in the Zintel Canyon flood plain by about 85 percent. Nonstructural measures would not be effective in preventing growth of future damage potential in the path of Zintel Canyon floodwaters through Kennewick as the area is already nearly fully developed. However, restrictions should be placed on development in the flood plain upstream from the considered project. Unless prevented by zoning, development may occur in suburban areas around Kennewick subject to flooding from canyons adjacent to Zintel.

Protection against flood damages by Little Klickitat River could be provided by upstream storage of about 50,000 acre-feet at any of three potential storage sites, or by levees. In view of the relatively small amount of flood damages, it is problematical whether any project would be feasible.

Measures considered necessary for protection of upland areas include 7,700 farm ponds and small reservoirs with a total of 20,000 acre-feet of storage, 560 miles of small levees, 4,900 miles of channel improvement in minor streams, 120 miles of channel stabilization, 1,900 miles of streambank protection and 900 miscellaneous stream structures. Cropland protective measures that would further reduce flood damages include 1,572,000 acres of conservation cropping systems, 440,000 acres of crop residue use, 600,000 acres of stubble mulching, and 5,424 miles of diversions and terraces. Needed forest land treatment measures include 339,300 acres of erosion control treatment and 4,540 miles of road and trail restoration for retardation of erosion. Required rangeland practices include grass seeding on 2.2 million acres and brush control on 2.8 million acres. Approximately 2.2 million acres are still overgrazed. Additional information on needed land treatment measures is included in Appendix VIII.

Comprehensive treatment programs comprising land measures and small flood control structures should be applied to 67 watersheds which have a total of 52,200 acres subject to flood damages. The works on these watersheds are included in the subregion totals of small flood control structures and land treatment measures cited above.

Bank Erosion

Approximately 10 percent of the seriously eroding stream-bank will require treatment prior to 2020. Along many of the smaller streams and in headwater areas, adequate protection can be achieved by use of vegetative measures at an average cost of \$8,000 per mile. Structural measures, predominantly riprap, will be required on the larger streams. It is estimated that riprap protection would cost \$40,000 per mile and that concrete retaining walls would cost \$200,000 per mile. Total costs of bank protective works in Subregion 7 are estimated to be \$7 million through 2020.



Bank erosion on Tygh Creek, 1965. (USCE)



LOCATION MAP

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SUBREGION 8

LOWER COLUMBIA

GENERAL

Location and Extent

The Lower Columbia Subregion lies mainly within the State of Washington (94 percent) with a small portion in Oregon that borders the Columbia River making up the rest, see figure 20. The area is essentially the drainages of the Cowlitz, Lewis, and several small rivers and the flood plain areas of the Columbia River west of Bonneville Dam and east of Grays Bay. It covers 5,103 square miles or about 2 percent of the total Columbia-North Pacific Region.

Small sections of Subregion 9, Willamette, and Subregion 10, Coastal, are included in this flood control analysis so that areas subject to flooding by the lower Columbia River and its tributaries may be considered as a unit.

Topography

The area has the wide range of topography and physiography which is characteristic of western Oregon and Washington. Elevations vary from Cascade Range summits, Mt. Rainier 14,408 feet, Mt. Adams 12,307 feet, Mt. St. Helens 9,677 feet, to less than 50 feet in the Columbia flood plain.

The two principal tributary rivers, Cowlitz and Lewis Rivers, rise in the Cascade Range and flow southwesterly to a confluence with Columbia River. These streams have cut into ancestral glaciated valleys and now flow through rather narrow canyons. The terrain is generally rugged and streams have gradients of 4 to 5 percent in headwater areas. The relatively flat Columbia River flood plain, which borders the western edge of the subregion, contrasts sharply with the rugged interior.

Essentially all of the landscape, except the floor of the Columbia and Cowlitz River valleys, is heavily forested.

Climate

The subregion occupies a trough-like area between the crests of the Coast and Cascade Ranges. The Coast Range protects the area from the more intense winter storms moving inland from the Pacific Ocean and the Cascade Range protects it from the higher summer and lower winter temperatures of eastern Washington. Most of the airmasses crossing the region have spent considerable time over the ocean and the maritime air has a moderating influence in both winter and summer. There is, however, a well defined dry season in summer and a rainy season in winter. From west to east, annual precipitation decreases along the leeward slope of the Coast Range from 90 inches or more at the crest to about 40 inches in the lower river valleys, then increases to 100 inches and more along the windward slope of the Cascades.

Economic Development

Population centers are at Vancouver, Camas-Washougal, Longview-Kelso, and St. Helens. The total population is relatively small (240,000 in 1965), and average density is 47 persons per square mile. Approximately 47 percent of the population is classed as urban, 53 percent rural. The economy is based on forest products harvesting and processing, production of aluminum, production and processing of food, waterborne commerce, and service industries.

Total employment in 1960 was 77,700. The largest basic employment category was forest products manufacturing, 18,700; followed by agriculture, 4,700; forest management, 2,000; and mining and primary metals, 1,700.

Emphasis is shifting from lumber production to paper, pulp- and chip-board, and plywood, and diversified industries are being added at cities that formerly depended on large sawmills. The deep-draft navigation channel has made cities along the Columbia River international ports of major economic importance and has fostered development of many large industries.

The subregion is effectively served by highway, rail, water, and air transport systems. Commerce and trade have, since early settlement, been of major economic significance. In fact, much of the incentive for settlement came from the geographic position of the area at the crossroads of rail and highway routes and the water route to the Pacific.

Streams

Subregion 8 includes the Columbia River and tributaries in Oregon and Washington below Bonneville Dam (except the Sandy and Willamette Rivers which are included in Subregion 9). Table 78 summarizes streamflow data for the most important tributaries, all of which are affected by backwater in their lower reaches during periods of high flows on the Columbia River.

Table 78 - Streamflow Summary for Selected Sites, Subregion 8

<u>Stream</u>	Total Drainage Area (Sq. Mi.)	Enters at Col. River Mile	Gage Station	Gage Drainage Area (Sq. Mi.)	Mean Annual Flow 1/ (cfs)	Momentary Flow 1/	
						Max. (cfs)	Min. (cfs)
Washougal	211	121	Washougal	108	-	19,900	41
Lake	115	88	None	-	-	-	-
Lewis	1,046	87	Ariel	731	4,752	129,000	1
East Fork Lewis R.			Heisson	125	741	15,600	29
Kalama	205	73	Kalama	198	-	16,600	155
Cowlitz	2,480	68	Castle Rock	2,238	8,932	139,000	998
Clatskanie	96	50		53	-	2,000	3
Elochoman	73	36	Cathlamet	66	368	8,530	18
Grays	124	21		56	-	10,700	23
Columbia	259,000	-	Mouth	-	235,123	-	-

1/ Observed values for period of record.

Source: Appendix V.

Flood Characteristics

Spring Floods

Most major floods in the Columbia River occur during the annual spring freshets, which result from the melting of snow throughout the headwaters. The magnitude and duration of the freshets are a function of the volume and areal distribution of the basin snow cover and the weather during April, May, and June. Freshets generally begin with the melting of snow from the southern foothills and increases gradually as the season advances accompanied by rising temperatures. Major flood discharges occur when there is an above average snowpack in the mountains, the basin weather remains cool throughout the early spring, then becomes unusually warm over the entire upper basin about the middle of May, and remains unseasonably warm for several weeks. Warm rains over the snowfields are usually a factor in producing maximum floods. The river may remain above flood stage for several weeks and may have several peaks over a 2-week period only slightly lower than the actual crest. Backwater from the Columbia River freshets extends up the Cowlitz and Lewis Rivers about 16 and 13 miles, respectively.

The Cowlitz and Lewis Rivers, the principal tributary streams, also have spring snowmelt but rarely with major overbank

flooding. Flood damages from spring freshets generally consist of land losses by erosion and channel changes.

Winter Floods

Winter floods in the Lewis and Cowlitz Rivers and other tributaries result either from prolonged heavy rain or from heavy rain augmented by snowmelt. Major floods occur between November 15 and March 15. Snowmelt has been a factor in all of the most damaging winter floods.

Winter flooding of lands along the Columbia River below Puget Island, mile 45, results from a combination of two or more of the following factors:

- a. High discharges from tributaries;
- b. Normal or above-normal flows in the Columbia River;
- c. Extreme high tides (about 2 feet above mhhw).

HISTORY OF FLOODING

Columbia River Floods

Twelve major floods of 26.0 feet or higher as measured on the Vancouver gage occurred during the 110-year period of record (1858-1968) on the Columbia River and are listed in table 79. Of these, the only one which occurred in winter was that of December 25, 1964. It was sixth in order of magnitude. The second largest winter flood occurred in December 1933. It caused maximum stages on the Lewis and Cowlitz Rivers and on several streams in adjoining Subregions 3, 9, 10, and 11, but the Columbia River reached a stage of only 23.1 feet on the Vancouver gage. However, the effects of the high flow, high tides, and wind and barometric hold-up caused the highest stages ever recorded on the Columbia River below mile 30. Similar conditions in December 1941 caused stages nearly as high.

Three notable spring floods, of years 1894, 1948, and 1956, are compared in the following paragraphs to the winter flood of December 1964. The comparison is summarized in table 80.

Table 79 - Major Floods, Columbia River at
Vancouver, Washington, Subregion 8

<u>Year</u>	<u>Day</u>	<u>Month</u>	<u>Gage Height</u> ^{1/} (ft.)
1894	7	June	34.4
1948	1 & 14	June	31.0
1876	24	June	29.7
1880	1	July	29.0
1882	14	June	27.8
1964	25	Dec	27.7 ^{2/}
1956	4-5	June	27.6 ^{2/}
1887	21	June	27.4
1933	19	June	26.3
1928	31	May	26.2
1921	12	June	26.0
1950	26	June	26.0

^{1/} Gage heights are referred to the USED and NWS gage at Vancouver.
Zero of the gage is +1.82 feet, m.s.l., 1947 adjustment.

^{2/} Regulated by upstream storage.

1894 Flood

The largest recorded flood on the Columbia River occurred in June 1894, although the historical flood of 1849 may have been equally large. (7) Little information is available as to antecedent conditions such as snowfall depths and water content in the tributary areas preceding the 1894 flood, as much of the region was sparsely settled and the records kept were generally for locations in the lower valleys of the main watercourses. It is known, however, that precipitation of about 160 percent of normal during the winter and spring of 1893-94 resulted in the accumulation of a deep snow cover over all of the mountainous areas. A cold period starting in the early spring and continuing later than normal was followed by an unusually warm period. Rapid melting of the snow cover in the latter part of May and June was caused by sudden and prolonged warm weather. Nearly all of the tributary streams throughout the basin east of the Cascades rose to flood stages equal to or greater than any that have occurred since records have been kept.

1948 Flood

The second largest flood recorded on the Columbia River reached its maximum stage at Vancouver on June 1 and again on June 14, 1948. (11) Between these dates, the river remained within a foot of the crest stage. Backwater from the Columbia River reached a crest of 30 feet, 12 feet above bankfull stage at Portland on the Willamette River.

In April 1948, the water content of the accumulated snow in the mountain areas of the Columbia River Basin was only 97 percent of normal, but spring was abnormally late. Snow survey data for May 1 indicated that in many areas the water content was greater than on April 1, a very unusual condition, and subnormal temperatures continued until May 15, which permitted the snow cover to remain on much of the basin. Temperatures rose on May 15, and after 2 weeks of warm weather, the runoff from the large snowmelt area caused near record floods in the basin. General rains on May 28 and May 29 were extremely intense in several localities and added to the seriousness of the flood in lower Columbia River. Weather conditions favorable to a high rate of snowmelt prevailed until June 10 and resulted in the flood remaining near crest discharges for a 2-week period. Exceptionally high tides during the flood added to the magnitude of crest stages downstream from St. Helens, Oregon. Probably the most significant factors that contributed to the extreme magnitude of the flood were the subnormal temperatures and the greater than normal precipitation in both April and May.

Maintenance, repair, and improvement of levees had been neglected along the entire lower Columbia River because of the scarcity of funds, materials, equipment, and labor during World War II. In addition, the occupants of the flood plains had been lulled into a sense of false security by the absence of serious flooding in preceding years. The floodwaters took a heavy toll of residences, industry, utilities, and commerce along the entire length of the Columbia River and up all the tributaries. At times, disaster came swiftly as when the homes of more than 18,000 people in Vanport City were completely destroyed in about 2 hours. The city was located in Peninsula Drainage District No. 1, a leveed, low-lying area between Portland and the Columbia River. Flood protection on the west and east sides of the district was provided by railroad and highway fills, respectively, which had not been constructed for use as levees. The flooding occurred when the railroad fill breached. The break quickly widened to 600 feet, and 10 to 20 feet of debris-laden water inundated the city.

In the 1948 flood over 115,000 acres were recorded as being flooded; 35,000 acres were in existing diked areas. The flooded areas included 42,000 acres listed as waste, of which 18,000 acres are omitted from current flood plain listings as they are assumed to have no potential for future development. Sixteen out of 63 diking or drainage districts were inundated either from levee failure or overtopping. Numerous other levees were damaged and required extensive rehabilitation. In many areas, the period of inundation was so long (ranging from 30 to 60 days with 8 to 15 feet of water) that all crops were killed.



Vanport, June 1, 1948. (USCE)

All forms of transportation and communications were disrupted. Both the railroad and highway approaches to the bridges across Columbia River between Portland and Vancouver were destroyed in the vicinity of Vanport; and the Portland railroad station and switchyards, the Portland International Airport, and most of the docks and shipping facilities in the Portland-Vancouver area were inundated. Much loss of production resulted, even at great distances from the flooded area, as a result of work stoppage and other closures within the area, and thousands of people were out of work.

Power production at Bonneville Dam was reduced to less than 30 percent of normal rated capacity for 3 weeks by high tailwater, and only the fact that so many industries were closed by the flood prevented a serious power shortage from developing.

1956 Flood

The potential for a major flood on the Columbia in 1956 began to develop late in 1955 when above-normal precipitation

thoroughly primed the soil prior to the initial snowfall. Snowfall was unusually heavy through the winter, and by April 1, 1956, the water content of the snowpack in the basin averaged about 140 percent of normal. In April, alternately warm and cool temperatures with less than normal precipitation melted the low elevation snow ahead of the main snowpack. The cool periods interspersed with the warm consolidated the snowpack, which had a dampening influence on any concentration of snowmelt runoff. Had the late-season weather in 1956 been similar to that in 1948, the 1956 flood in all probability would have approached the magnitude of the 1894 flood.

Following the disastrous 1948 flood, governmental agencies and private concerns had established a system of forecasting potential flood hazards and a cooperative means to effect the maximum control with existing storage facilities. This forecasting system alerted the region to the potential flood situation. Accordingly, all available upstream storage was used. The crest on the Vancouver gage was reduced by 2.4 feet. Extensive advance preparations were made by local drainage districts, the Corps of Engineers, and private industrial and commercial firms. Levees were strengthened and raised; new levees were constructed; livestock, merchandise, and equipment were either moved to higher ground or prepared for rapid evacuation; and supplies and equipment needed to fight a flood were accumulated.

Most areas were protected; however, levees in five districts with a total area of 9,800 acres were overtopped or breached causing considerable damage.

The stability of the levees protecting several other districts was very uncertain, and several hundred residents evacuated their homes, while many others prepared to leave. No major highways or railroads were closed, but many local roads were inundated, and access roads and spur tracks serving many industries were closed for varying periods of time.

1964 Flood

The conditions which produced the December 1964 flood are described under Subregion 9. The storms covered a wide area and major flooding occurred throughout the far western states from the Columbia to the San Joaquin and as far inland as Reno, Nevada, and Pocatello, Boise, and Lewiston, Idaho. (4)

Along the Columbia River above the confluence of the Willamette, floodflows were significant but not of major spring proportion. Except for the complications of an extraordinary

debris load caused by violent flooding on tributary streams, which caused operational problems at Bonneville and The Dalles Dams, flood damages were minor above Vancouver. However, below the confluence of the Willamette, the flood was the greatest winter flood of record (backwater from the Willamette also affected the Columbia stages for several miles upstream). Nearly half of the damages were sustained by commercial and industrial properties. The greatest portion were in timber-based industries, and included loss of sawlogs, lumber, and damages to machinery. Other commercial and industrial losses included damages to docks, machinery works, grain elevators, packing plants, and small industrial enterprises in the Camas to Longview area. Agricultural losses were next in importance, and debris damaged the Vader, Washington water system and several privately owned hydroelectric facilities. Total damages in the subregion are shown in table 80. It is significant to note that, although the crest in 1964 was higher at Portland and nearly the same at Vancouver as in 1956, the total damages in the subregion were much greater in 1956, due primarily to the longer period of flooding.

Table 80 - Comparison of Major Columbia River Floods, Subregion 8

	June 1894	June 1948	June 1956	Dec 1964
Flood Crest Stages <u>1/</u>				
Vancouver				
Observed ft.	34.4	31.0	27.6	27.7
Unregulated ft.	34.4	31.0	30.0	32.5
Portland				
Observed ft.	33.0	29.95	26.4	29.85
Unregulated ft.	33.0	30.0	28.7	34.4
Days Duration above Flood Stage <u>2/</u>				
Bankfull	74	51	70	9
Major flood	38	26	12	2
Damages in \$1,000 <u>3/</u>	<u>4/</u>	\$79,979.0	\$9,763.0	\$6,788.0
Lives lost <u>3/</u>	<u>4/</u>	18	None	None
<u>1/</u> National Weather Service gage heights in feet. Zero of Vancouver gage is +1.82 feet, m.s.l. Zero of gage at Portland is +1.55 feet. <u>2/</u> Flood or bankfull stage for Columbia River is 16 feet at the Vancouver gage. A flood of 26 feet or higher results in extensive damage and is considered a major flood. <u>3/</u> Subregion 8 only. <u>4/</u> Not available.				

Major Floods on Tributaries

The most devastating flood on Lewis and Cowlitz Rivers occurred in December 1933 with peak flows of 129,000 cfs at Ariel and 139,000 cfs at Castle Rock, respectively. However, little information other than peak flows is available on that or other floods prior to 1964.

Table 81 - Major Floods Lewis and Cowlitz Rivers, Subregion 8

	<u>Date of Flood</u>	<u>Peak Discharge</u> (cfs)
Lewis River at Ariel	Dec 1933	129,000
	Dec 1917	66,000
	Dec 1955	49,100
	Nov 1949	49,000
	Dec 1964	41,600 ^{1/}
Cowlitz River at Castle Rock	Dec 1933	139,000
	Dec 1946	85,100
	Dec 1964	83,900
	Nov 1927	74,000

^{1/} Affected by upstream reservoir storage and/or diversions.

During the 1964 flood, power dams on the Lewis River effected an appreciable but unevaluated stage reduction in the lower reaches. Three protected areas were flooded; however, two were overtopped by backwater from the Columbia, and the other was on the East Fork Lewis River, which is uncontrolled. On the Cowlitz River, a major slide caused extensive damages at the Mayfield Dam, a City of Tacoma hydroelectric project, where the floodwaters softened and undercut a large area adjacent to the spillway, causing a massive landslide which destroyed fish ladders and facilities and plugged the tailrace. The cleanup and restoration costs for the single facility amounted to over \$2 million, more than two-thirds of the total loss in both the Lewis and Cowlitz River Basins. (4)

PRESENT STATUS

Existing Measures

Flood Control Storage

Columbia River Control By 1973, when all projects presently under construction are completed, more than 43.5 million acre-feet of joint use storage space will be available on a forecast basis for control of the Columbia River spring floods. Of that storage nearly 12 million acre-feet will be on call storage in Canada (see footnote 4, table 82). An additional 500,000 acre-feet are

prescribed in the licenses for Priest Rapids and Wanapum Dam, but arrangements for use of this space have not been made. Table 82 shows how the storage would be used to control the 1894, 1948, and 1956 floods. The 1894 flood would be controlled to 668,000 cfs and the 1948 and 1956 to 642,000 and 509,000, respectively. A standard project flood would be reduced from 1,550,000 cfs to 840,000, about 28.7 feet on the Vancouver gage. Control of winter floods is mainly accomplished by the Willamette River projects in Subregion 9. However, some upstream space would normally be available in Arrow, Pend Oreille, and Dworshak Reservoirs, and forecasts would probably allow time to evacuate about 300,000 acre-feet from John Day Reservoir.

Table 82 - Storage for Control of the Main Columbia River, Subregion 8

		1894 Flood	1948 Flood	1956 Flood
Observed Peak, Cfs		1,240,000	1,010,000	823,000
Unregulated Peak, Cfs 2/		1,140,000	973,000	868,000
Regulated Peak, Cfs		668,000	642,000	509,000
Regulated Stage at Vancouver, Feet		22.4	21.6	17.0
Regulated Duration above 16' at Vancouver, Days		43	29	50

River	Maximum Storage Usable for Control of Columbia River Floods (1,000 ac.-ft.)	Storage Needed and Available in Excess of Natural Storage (1,000 ac.-ft.)			
Mica 4/	Columbia	12,000 4/	9,500	5,265 9/	7,170
Arrow Lakes	Columbia	7,100	4,618 5/	5,645	5,681
Libby	Kootenai	4,965	4,965	4,965	4,965
Duncan	Duncan	1,347	1,299	1,248	1,318
Kootenay Lake 6/	Kootenay	453 6/	-345 6/	-686 6/	-630 6/
Hungry Horse	S. F. Flathead	2,982	2,110	1,590	1,812
Flathead Lake	Flathead	1,219	107	594	423
Noxon Rapids	Clark Fork	231	219	231	231
Pend Oreille Lake	Pend Oreille	1,155	-53	232	332
Grand Coulee	Columbia	5,232	5,232	5,232	5,232
Jackson Lake-Palisades	Snake	1,600	1,150	648 7/	1,142 7/
Boise River Reservoirs	Boise	988	240	389 7/	739 7/
Cascade-Deadwood 8/	Payette	815	420	392	664
Brownlee	Snake	980	980	980	980
Dworshak	N. F. Clearwater	2,000	1,860	1,987	1,987
John Day	Columbia	500	500	500	500
Total		43,567	32,802	29,212	32,546

- 1/ With approximate 1970 level of irrigation development as shown in Appendix IX, Irrigation, and 1975 energy requirements.
- 2/ Flow adjusted to eliminate any effect of project storage at time of flood and include irrigation depletion effects as of 1970.
- 3/ Including natural storage. Actual amount available each year is dependent on projected runoff and power needs during previous winter.
- 4/ The Canadian Treaty stipulates that the flood control storage in Mica Reservoir is limited to 80,000 acre-feet, except that a portion of the Arrow Lakes storage space may be transferred to Mica Reservoir if agreeable to the United States. Additional space, up to 12 million acre-feet will be available in Mica Reservoir as on-call storage. A payment of \$1,875,000 by the United States is required for each of the first four times on-call space is requested, after which it will be provided at no additional cost if required.
- 5/ Reservoir filled 2 feet above usual maximum to provide flood control in the vicinity of Trail, B. C.
- 6/ The storage that can be controlled in Kootenay Lake amounts to 453,000 acre-feet. Historically, the natural surcharge storage in the lake has reached approximately 3,800,000 acre-feet. Storage in Libby and Duncan Reservoirs replaces some of this natural storage.
- 7/ Kootenay Lake regulation conforms insofar as possible to the International Joint Commission orders of November 11, 1938.
- 8/ Includes storage and regulation required to meet 1970 levels of irrigation.
- 9/ There is no authority for requiring flooding control storage space in Deadwood and Cascade Reservoirs but the U. S. Bureau of Reclamation normally regulates reservoirs to provide flood control space on the basis of seasonal runoff forecasts.
- 9/ Forecasts based on 1948 data do not indicate a need for on-call Canadian storage; power requirements would have drawn Mica Reservoir down as shown.

Tributary Control Plan Several major reservoirs have been developed by non-Federal agencies in the Lewis and Cowlitz River Basins, but only those on the Cowlitz River have any requirements for regulating floods. The Federal license for Mossyrock and Mayfield Reservoirs requires that these projects regulate a December 1933 flood on Cowlitz River to 70,000 cfs at Castle Rock. During the season of greatest flood hazard, 360,000 acre-feet including 100,000 acre-feet of surcharge and 260,000 acre-feet of joint-use storage, are reserved for flood control. The license further provides that floodwaters stored in surcharge space be evacuated as fast as downstream channel conditions permit, but preferably not to exceed a regulated flow of 50,000 cfs at Castle Rock. When the surcharge space is evacuated, further releases may be made through the power units so long as maximum use is made of this means to draw the reservoirs down to the scheduled storage reservations. The projects on Lewis River do not have any requirements for flood control except that releases in the lower river should not exceed natural flow conditions. However, the reservoirs have a total active storage capacity of 882,530 acre-feet and do provide some incidental regulation of floodflows. Approximately 520 farm ponds and small reservoirs have a total capacity of 2,600 acre-feet.

Levees and Bank Protection

The lower Columbia River system of local protective works consists of bank protection and levees constructed or improved with Federal funds in cooperation with local interests, plus numerous levees constructed entirely by local interests. The land areas which comprise the lower Columbia River flood plain are not continuous and do not extend far from the river. Levees were initially adopted as the only feasible means of protection against flooding and are still necessary to complete the protection afforded by storage. The economic development of the extreme lower river promoted construction of the first levee at Warrenton, Oregon, in 1899. Between 1915 and 1921, 11 or more drainage districts were organized, and the areas protected by levees were provided with pumping plants and tide boxes. New districts were organized and old ones reorganized along both riverbanks between 1935 and 1940 to obtain Federal funds and assistance for flood protection works under the provisions of the 1936 Flood Control Act. Of the 170,000 acres in the flood plain, about 110,500 acres are protected by levees and drainage facilities. Nearly 2,000 acres have been added to the protected area since the 1948 flood. Local interests have constructed 128 miles of levees, 100 miles of stream channel improvement and stabilization, 129 miles of streambank protection, and other miscellaneous stream structures along tributary streams.

Watershed Protection

Watershed protection measures which are used on croplands to reduce erosion and sedimentation and assist in reduction of flood damages include conservation cropping systems on 121,000 acres, crop residue use on 24,000 acres, and 871 miles of drainage conduits or ditches. More than 275,000 acres receive adequate treatment. Forest land protective measures have been limited to erosion control seeding and gully stabilization on 100 acres and rehabilitation of 100 miles of roads and trails. Significant rangeland practices include grass seeding of 700 acres and brush control on 1,700 acres. It is estimated that the soils of Subregion 8 have a total water holding capacity of 1.44 million acre-feet or 5.43 inches over the entire area. With proper soil management and under ideal weather conditions, most of this storage would be filled prior to formation of a major flood. Additional information on land treatment is included in Appendix VIII.

Table 83 - Existing Local Protection Projects, Subregion 8

<u>County</u>	<u>Number of Locations</u>	<u>Acres Protected</u>	<u>Total Length Levees, Miles</u>	<u>Total Length Revs, Miles</u>
<u>Washington</u>				
Clark	6	11,200	31	0.5
Cowlitz	9	21,700	30	2.5
Wahkiakum	6	11,800	62	5
Pacific	1	1,600	1	1.0
Total Washington	22	46,300	125	9
<u>Oregon</u>				
Multnomah	6	23,800	60	13
Columbia	16	24,900	63	12
Clatsop	22	15,500	73	13
Total Oregon	44	64,200	196	38
Subregion Total	66	110,500	321	47

Flood Forecasting

The National Weather Service Portland River District Office is responsible for the flood warning program and issues warnings for five key stations in Subregion 8. Table 84 shows the river locations, flood stages, and corresponding discharge.

Flood warnings are issued when forecasts indicate that near bankfull stages are expected. When flood stage is reached,

forecasts are issued at 12-hour intervals or more frequently if weather conditions change radically. Forecasts are released until streams recede to below bankfull stages and all danger is passed.

Cooperation is maintained with State, county, and city authorities; Federal agencies; Civil Defense officials; private and public utilities; and the news media (radio, television, and newspapers). Dissemination methods used in various phases may include radio and television announcements, loudspeaker trucks and aircraft, or door-to-door patrols by civilian defense workers and State, county, and city police.

Table 84 - Flood Warning Locations, Subregion 8

<u>Location</u>	<u>Stream</u>	<u>Flood Stage</u> (Feet)	<u>Discharge</u> (Cfs)
Vancouver	Columbia River	16	426,000
St. Helens	Columbia River	17	-
Kalama	Columbia River	20	-
Longview	Columbia River	12	563,000
Kelso	Cowlitz River	23	*

* Rating curve affected by backwater of Columbia River.

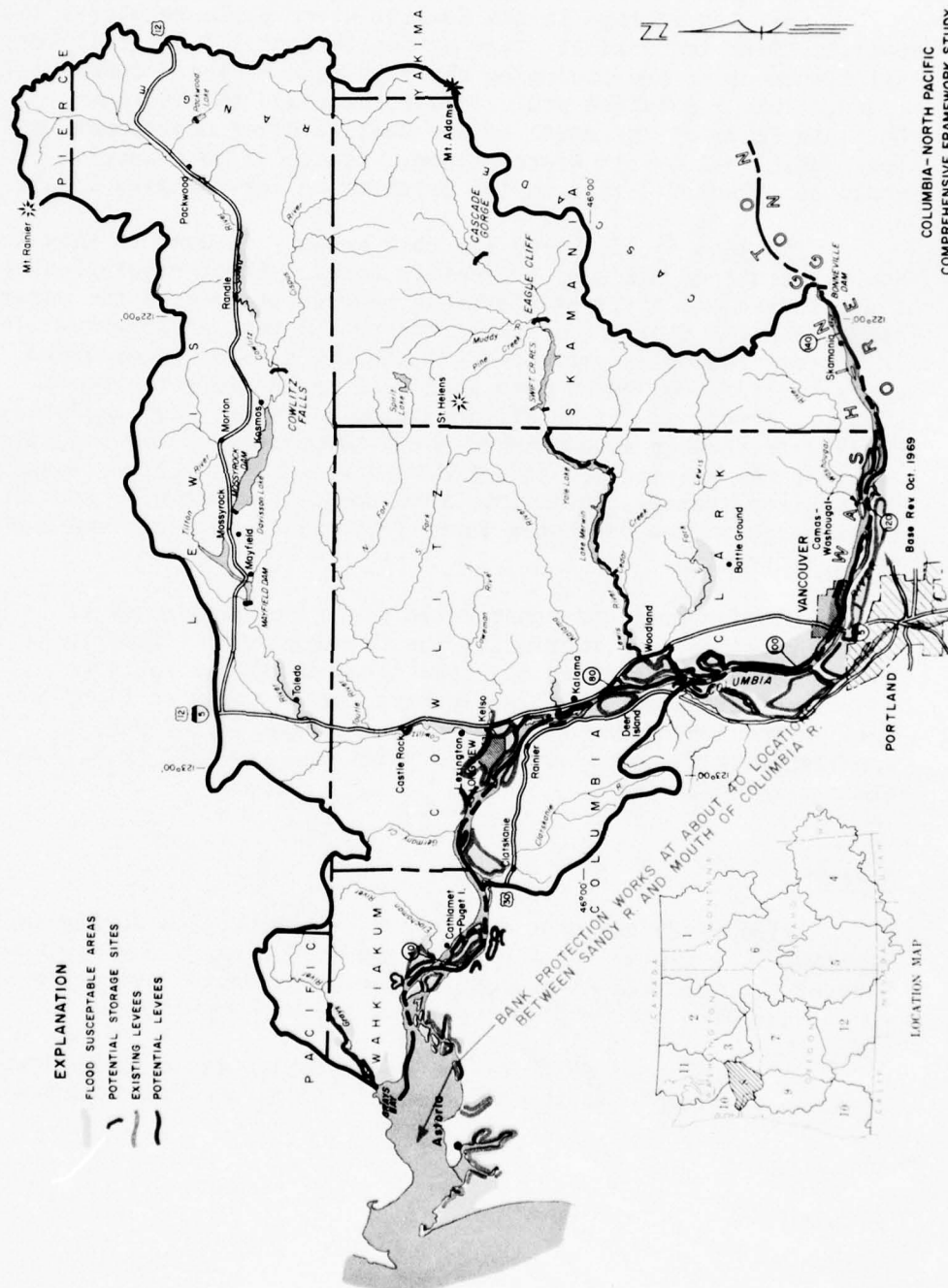
Flood Plain Regulation Programs

A flood plain information study has been made of Cowlitz County to include the flood plain areas associated with the Cowlitz, Kalama, Lewis, and Columbia Rivers, and the Coweman and Toutle Rivers, tributaries of the Cowlitz River. It was coordinated with all local, State, and Federal agencies which have an interest in evaluating the hazards of development in areas subject to periodic flooding. The report was published in January 1969.

Accomplishments

Storage

The upstream storage under construction and presently available will reduce floods equivalent to those of 1894, 1948, 1956, and December 1964, to 22.4, 21.6, 17.0, and 22.0 feet on the Vancouver gage, respectively. A standard project flood would be held to 28.7 feet. This degree of control can be achieved only by making optimum use of all available storage and would not be



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY
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FLOOD CONTROL FACILITIES**
LOWER COLUMBIA SUBREGION 8

possible without the flood forecasting program. With this degree of control, most levees along the lower river should not be overtopped with a repeat of any known flood although surveillance and emergency measures would be needed. However, many levees need strengthening to withstand the long duration of high river stages during major floods, see table 82.

Existing storage in the Cowlitz River Basin regulates the Cowlitz River to bankfull stage at Castle Rock (70,000 cfs) for all floods up to and including the magnitude of the December 1933 flood. This regulation would reduce the stage on the lower Columbia River at the mouth of the Cowlitz River approximately 1 foot during a 100-year winter flood. Little or no reduction would be effected during spring freshets on the Columbia River.

The 1964 flood, being the most recent, is used to show accomplishments of existing protective works. Flood regulation by the Columbia and Willamette storage reservoirs lowered the water stage nearly 5 feet at Vancouver and over 3 feet at Longview. (4) This stage reduction prevented \$27,400,000 damages in unleveed areas and \$39,600,000 damages in leveed areas along the lower Columbia River, see table 85. Hydrologic studies indicated that Willamette storage accomplished about 60 percent of the reduction, and that the balance was effected by mid and upper Columbia and Snake River storage, including Grand Coulee and Brownlee Reservoirs and storage in the Deschutes Basin (Prineville, Ochoco, and Round Butte Reservoirs).

Storage projects constructed since the 1964 flood or authorized for future construction in the Columbia and Willamette River Basins would have reduced the 1964 flood height at Vancouver an additional 5.7 feet, which would have further reduced flood damages in the subregion by \$3,500,000, of which \$2,800,000 would be creditable to Columbia River reservoirs and \$700,000 to Willamette Basin reservoirs.

Levees

Five levee failures occurred in the subregion during the December 1964 flood. Of the many protected areas along the lower part of the Columbia River, only three areas above river mile 30 would have been safe without upstream storage regulation.

The uppermost district in Oregon, which is 18 miles upstream from the confluence of the Willamette, would have had adequate

freeboard even without regulation. In Multnomah No. 1, the levee freeboard would have been encroached upon slightly at the lower end, but from midpoint upstream would have exceeded the stage by 3 feet. The levee is structurally sound and was credited as safe considering the short duration of the December flood. The levee protecting Longview, Washington would have had more than adequate freeboard; and, although some structural conditions of the levee were questionable, during such a short flood the levee was considered safe.

Table 85 is a list of levee improvement districts in the lower Columbia River between Troutdale and river mile 30, showing flood damages prevented and credit assignment to upstream storage or levee protection. Below river mile 30, the flood was no more serious than frequently occurs from storm and tidal effects alone, and no levees failed.

Table 85 - Flood Damages Prevented, 1964 Flood, Subregion 8

Description	County	Columbia River Mile	Damages Prevented	
			by Levee	by Storage
Oregon				
Sandy Drainage Dist.	Multnomah	110.5	\$ 5,200,000	-
Multnomah D. D. No. 1	"	108.0	18,000,000	-
Peninsula D. D. No. 2	"	106.5	-	\$ 5,800,000
Peninsula D. D. No. 1	"	105.0	-	6,600,000
Sauvie Island D. D.	(Multnomah- Columbia)	97.0	-	5,500,000
Scappoose D. D.	Columbia	90.0		1,760,000
Drainage Dist. No. 1	"	95.0	Flooded	Flooded
Deer Island D. D.	"	76.8	-	450,000
Rainier D. D.	"	62.6	-	960,000
John D. D.	"	56.0	-	73,000
Beaver D. D.	"	56.0	-	2,160,000
Clatskanie D. D.	"	50.0	-	360,000
Magruder D. D.	"	47.6	-	190,000
Midland D. D.	"	47.4	-	570,000
Webb Dist. Impr. Co.	"	46.0	-	240,000
Marshland D. D.	"	45.6	-	520,000
Woodson D. D.	"	45.0	-	132,000
Westland Dist. Impr. Co.	"	44.0	-	380,000
Drainage Dist. No. 15	(Columbia- Clatsop)	43.4	-	41,000
Drainage Dist. No. 6	Clatsop	34.6	-	160,000
Washington				
Fruit Valley Homes	Clark	104.7	-	223,000
Drainage Dist. No. 14	"	99.4	Flooded	Flooded
Lake River Delta	"	90.0	-	220,000
Consol. D.I.D. No. 2	Cowlitz	84.2	-	6,800,000
Consol. D.I.D. No. 3	"	68.8	-	3,500,000
Consol. D.I.D. No. 1	"	60.7	33,000,000	-
D.I.D. No. 15	"	58.6	-	660,000
Consol. D.D. No. 1	Wahkiakum	38.8	-	1,940,000
Drainage Dist. No. 4	"	36.0	-	310,000
Drainage Dist. No. 5	"	33.0	-	260,000
Total			56,200,000	\$39,596,000

A Federally constructed levee at Castle Rock prevented Cowlitz River from flooding of a large portion of the town. Damages prevented are estimated at \$100,000.

A Federally constructed levee project was completed in 1965 for the protection of 1,800 acres on the Washington shore near Washougal. This levee would have prevented \$12,000 damages in the December 1964 flood.

An authorized local protection project for 530 acres in the Kalama, Washington area would have prevented \$14,000 damages in the December 1964 flood.

Bank Protection

Bank protection is a part of an overall plan for flood control along Columbia River in the subregion. It consists of protective works for an estimated 134,000 lineal feet of eroding banks at some 61 locations, providing protection to critical areas. The authorized project was 20 to 25 percent completed at the time of the flood of December 1964 and prevented an estimated \$130,000 in damages.

Comprehensive Watershed Treatment Programs

Comprehensive treatment programs on three watersheds have reduced damages on 4,000 acres from \$42,000 annually to \$2,000.

Flood Problems

The flood plains along the lower Columbia River comprise about 110,000 acres which are protected to various degrees by levees and another 60,000 acres which lie in the flood plain but have no local protection works. Approximately one-third of the protected lands need additional drainage facilities and/or levee improvement for full utilization and protection against major floods. Of the flood plain land presently protected, 72 percent is in agriculture, 23 percent is developed for industrial and urban use, and the remaining 5 percent includes sloughs, roads, brush, and waste areas. The unprotected lands include swampy, undeveloped lands, lands that are flooded too rarely to have warranted protection, and areas that have been too expensive to protect.

The lower Columbia flood plain from Portland to the Pacific comprises much of the existing and potential industrial lands of

southwestern Washington and northwestern Oregon. These lands have a high industrial value derived from the variety of transportation readily available, abundance of fresh water, access to continental and world markets, and many other advantages. The flood plains also contain much of the agricultural lands of the subregion. Flood problems are thus associated with both agriculture and industry. Because of flooding, or the threat of flooding, certain agricultural lands are limited to less than full or highest return use.



Architect's model of possible development underway in the Rivergate area at the confluence of Columbia and Willamette Rivers. (Herbert Bruce Cross photo)

Several major industrial plants are located adjacent to the river and additional industrial areas are being developed. Such major developments are provided a very high degree of protection at the time of construction, but many smaller plants are subject to frequent flood damage.

Usage of the available land could be further enhanced by flood protection and drainage. As an example, an interim report

shows land in the Vancouver Lake, Washington area has an existing value of approximately \$1,250 per acre. The land is presently used for dairying, livestock raising, row crops, and recreation. The land is estimated to have a value of \$11,000 an acre as industrial land if it were flood-free and if adequate utilities and transportation were provided at nominal cost. Another area at the mouth of Willamette River, which at present is flooded to such a degree that it is largely waste, is under development by the Port of Portland as an industrial area. Other areas exist where levees are not adequate to prevent damage from a controlled standard project flood (840,000 cfs).

Bank erosion on approximately 100 miles of seriously eroding streambank causes \$609,000 average annual damages including land loss, sedimentation, and other miscellaneous losses. Much of the eroded material moves on down the Columbia River and out to sea. The amount actually carried to sea has not been determined but the beach sands from Tillamook Head to the Willapa Bay entrance originated in the Rocky Mountains and were carried to sea by the Columbia River. Uncompleted studies using radionuclide tracers and other modern techniques indicate that a large percentage of the material transported by the river is being deposited in the estuary. More than 2 million cubic yards of silt and sand are dredged annually from the navigation channel at the mouth of the Columbia River and dumped at sea. The percentage of this material deriving from beach sands and the percentage from the river has not been determined.

Table 86 lists average annual damages from flooding by major and minor streams and from streambank erosion as an indication of the remaining flood problems.

Table 86 - Average Annual Damages, Subregion 8 ^{1/}

	1967 Development			1980	2000	2020
	Rural	Urban	Total			
Oregon						
Major Streams	784	109	893	1,170	1,867	3,105
Minor Streams	56	0	56	74	110	163
Washington						
Major Streams	448	56	504	660	1,047	1,726
Minor Streams	1,346	351	1,697	2,240	3,326	4,938
Bank Erosion	456	153	609	629	761	918
Totals	3,090	669	3,759	4,773	7,111	10,850

^{1/} In \$1,000, 1967 prices, 1970 (Incl. U.C.) storage, winter and spring floods.

PROJECTIONS AND NEEDS

Economic Trends

Population projections show Subregion 8 to grow at a slower rate than that of the region as a whole. In 1965, the population of the subregion was 240,100, and projections are for populations of 277,900 in 1980; 349,400 in 2000; and 441,300 by 2020. This represents a growth rate of about 1.1 percent per year. Most of this growth is projected to take place at the larger urban centers of Vancouver, Longview-Kelso, Camas-Washougal, and St. Helens. The smaller incorporated places will grow at a slower rate, while little or no growth is expected in rural areas. Agricultural production is expected to increase, despite a decline in employment in agriculture, through more efficient use of labor and greater capital investment per worker. Employment growth will take place primarily in pulp and paper, primary metal production, secondary manufacturing (fabricated products) of lumber and aluminum goods, textiles, food processing, and the service industries.

Land-Use Trends in the Flood Plain

Use of most flood plain areas along the lower Columbia River is expected to intensify. Industries heavily dependent on transportation are expected to locate where they will have access to the navigation channel. Other industries, commercial facilities, and residential developments will locate in nearby areas where partial protection by upstream storage and existing levees lends a sense of false security. Agricultural areas not usurped by industrial and urban expansion will produce greater yields of existing crops or be changed to higher cropping patterns. Use patterns except for increased agricultural yields are not expected to change in the flood plains along tributary streams including Lewis and Cowlitz Rivers.

Future Flood Damages

Urban

Urban damages, including commercial, industrial, and transportation damages, are projected to increase at the growth rate for total personal income. The heavy industries that are expected to locate along the navigable waterway will largely be flood proofed as constructed. The projections of future damages allow for this in that future totals are based on present day averages and the existing heavy industries are generally not subject to flood damages.

Rural

Agricultural production is expected to increase from 1-1/2 percent to 2 percent per year. Considering the proximity to major urban centers and the productivity of flood plain soils, more intensive cropping practices also are expected. On these bases, rural flood damages are projected to increase at 2 percent per year.

Summary of Flood Control Needs

With total average annual damages projected to increase from \$3.76 million to nearly \$11 million by 2020 (see table 86), there will be a need for additional flood control measures in selected areas to prevent damages. There will be an even greater need for flood control measures in unprotected areas and tributaries to permit optimum land usage.

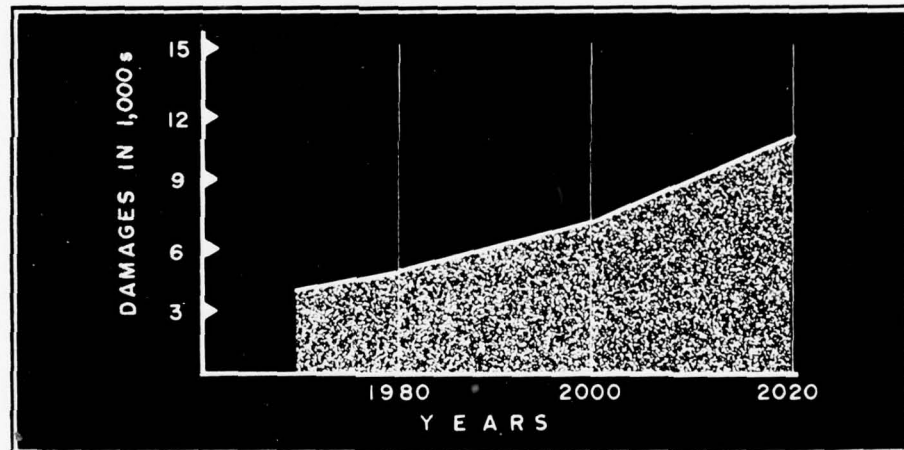


Figure 21. Projected Average Annual Flood Damages, Subregion 8.

MEASURES REQUIRED TO SATISFY NEEDS

Storage

Columbia River

Additional upstream storage that could be effective in control of the lower Columbia River would add flexibility and reliability to the existing system and would effect stage reductions during very infrequent major floods. However, since the existing system is capable of controlling all known floods to

relatively minor proportions the unit value for flood control of any additional storage would be relatively small. It has been estimated that future upstream storage would have an annual value of about 14 cents per acre-foot in preventing present and future damages and permitting more intensive land use.

Tributary Streams

Storage is not a practical solution to flood problems in the Lewis River Basin as the flood plain area above the influence of the Columbia River is very small. Existing private power projects provide incidental flood control benefits, and there are little remaining damages that could be benefited by additional storage. Two potential storage sites are shown on table 87. An application has been filed with the Federal Power Commission for a license to build the Muddy project on the Lewis River at about the same place as Eagle Cliff. If built, Muddy would provide up to 277,000 acre-feet of usable storage, part of which could be used for flood control if warranted. Justification of additional storage on Cowlitz River does not appear likely at this time, but a potential site is shown on table 87.

Table 87 - Potential Flood-Control Storage Sites, Subregion 8

<u>Basin and Stream</u>	<u>Site</u>	<u>River Mile</u>	<u>Drainage Area (Sq. Mi.)</u>	<u>Potential Flood Control Storage (Ac.-Ft.)</u>
Lewis River Basin:				
Lewis	Cascade Gorge	70	146	45,000
	Eagle Cliff	60	375	100,000
Cowlitz River Basin:				
Cowlitz	Cowlitz Falls	89	1,000	300,000

Levees

Approximately 43,200 acres along lower Columbia River and 3,340 acres on upper Cowlitz River are in need of additional flood protection. To provide that protection, about 66 miles of new levees and 59 miles of improvement to existing levees would be required. This work would cost about \$32.4 million (table 88) It is not anticipated that need will arise for additional levees on Lewis River before the year 2020.

Channel Improvement and Stabilization

The channel of the Cowlitz River downstream from Mayfield Dam could be improved and stabilized by channel clearing, channel rectification, and revetment at critical points. The location and magnitude of the reaches needing improvement will not remain fixed, but will change as erosion occurs.

Zoning, Forecasting, and Emergency Operations

The distribution of flood plain information and furnishing of technical assistance to local government units will need to be expanded. This service will promote establishment of local zoning regulations to slow the increase in flood-damage potential.

Existing and possibly improved flood-forecasting techniques will make it possible to give ample warning of impending disastrous floods and will facilitate emergency flood-proofing and evacuation. Because the subregion is located on the downstream end of a large watershed, flood warning can be given from several days to several weeks before arrival of major flood peaks. With improved techniques, it will be possible to forecast, with a high degree of accuracy, the flood stage to be expected.

Watershed Protection and Upland Areas

A combination of improved management practices, land treatment measures, and water control structures will be necessary to satisfy future watershed needs for flood prevention. The cropland practices that are still needed are 27,000 acres of conservation cropping systems, 19,000 acres of crop residue use, and 1,897 miles of drainage conduits. Forest land treatment measures needed include 20,600 acres of erosion control treatment and 775 miles of road and trail restoration. Rangeland practices required include 1,000 acres of brush control.

Needed structural measures on small upland streams include 500 ponds and reservoirs with 1,500 acre-feet of storage, 72 miles of levees, 341 miles of stream channel improvement, 37 miles of stream channel stabilization, 629 miles of streambank protection, and 49 miscellaneous other stream structures.

Bank Protection

On the Columbia River, additional revetment protection is needed in numerous locations to prevent erosion damages, primarily from wave wash. An additional 120 miles of revetment is estimated

Table 88 - Estimated Expenditures for Levee Protection,
Subregion 8

	Present to 1980	1980 to 2000 (Millions of Dollars)	2000 to 2020	Total
<u>Washington</u>				
New levees	1.1	10.1	11.1	22.3
Improved levees	3.5	3.8	2.3	9.6
<u>Oregon</u>				
New levees				
Improved levees			1.7	1.7

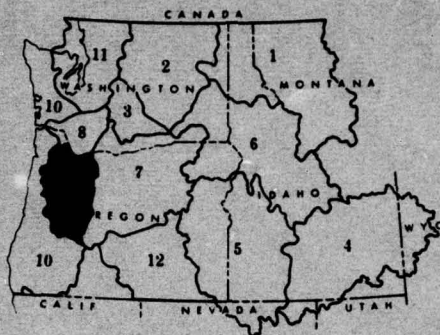
to be needed in the subregion by the year 2020. The cost of that work is estimated at \$6 million. An estimated 57 miles of seriously eroding streambank on other streams should have protection prior to year 2020. Cost of bank revetment would range from \$250,000 per mile on the Cowlitz and Lewis Rivers to \$40,000 per mile on smaller streams with drainage areas less than 400 square miles. Estimated total cost of this additional bank protection work would be in the order of \$5,400,000 before the year 2020.



Riprap along the lower Columbia River. (USCE)

Comprehensive treatment programs comprising land measures and small flood control structures should be applied to 44 watersheds which have a total of 75,200 acres subject to flood damages. The works on these watersheds are included in the subregion totals of small flood control structures and land treatment measures cited above.

Additional information of the land treatment measures is included in Appendix VIII.



LOCATION MAP

20-000000

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SUBREGION 9

WILLAMETTE

GENERAL

Location and Extent

Subregion 9 includes the drainage basins of the Willamette River, the Sandy River, and the small streams that enter the Columbia River from the south between Bonneville Dam and St. Helens, Oregon. It is the area for which a multiagency type 2 study was completed in 1970. It covers an area of 12,046 square miles in northwestern Oregon and is roughly rectangular, with a maximum north-south dimension of about 150 miles and an average width of about 80. In this appendix, those flood plain lands in this subregion lying along Columbia River are included with the presentation for Subregion 8.

Topography and Climate

The generally low elevation of the subregion with mountain ranges on the periphery, and abrupt changes from steep mountains and foothills to the nearly level valley floor contribute to the formation of floods and their characteristics. Climatic factors include the proximity of the Pacific Ocean, the predominantly west-to-east movement of airmasses, the annual pattern of arid summers and heavy precipitation during the winter months, and the occasional invasion of the area by cold continental airmasses. Topography and climate are described in detail in Appendixes II - The Region, and V - Water Resources, respectively.

Economic Development

The estimated population of Subregion 9 in 1965 was 1,338,900, or 63 percent of that of the State of Oregon. The basin contains three Standard Metropolitan Statistical Areas: Portland, Eugene, and Salem; with populations in 1966 of 929,200 ^{1/}, 201,000, and 182,000, respectively. Of the 1 million persons who live in urbanized areas, cities, and towns in the basin, more than

^{1/} Clark County, Washington, which is not part of this subregion, is included in the Portland SMSA.

900,000 reside within 10 miles of Willamette River. Less than 6 percent of the total basin population resides on farms. Figure 10 shows the close correlation between the heavily populated area and the flood plain.

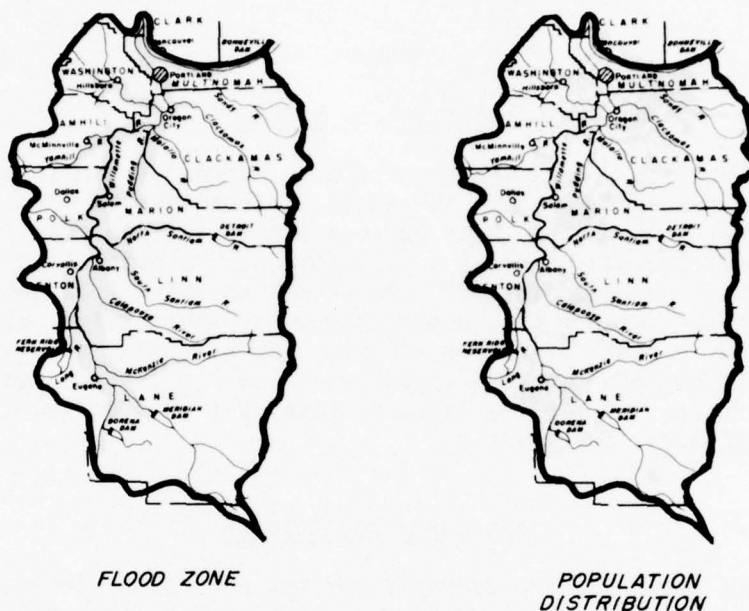


Figure 22. Population Density is Highest in Flood Prone Areas.

The earliest settlements were located adjacent to Willamette River to take advantage of water transportation, and many grew to become the cities of today. Of the 10 cities with populations of 10,000 or more, all but two are located on the banks of Willamette River and have developments in the flood plain. Flood-plain areas are farmed extensively and contribute significantly to the basin's production of 22 percent of the Nation's mint harvest, 23 percent of snap beans, 19 percent of hops, 99 percent of ryegrass seed, as well as significant proportions of many other crops.

The subregion is served by railroads which connect to the nationwide system, and by a network of State and U. S. highways generally following the valleys of the major streams. All-weather roads reach all cities and towns not on major highways. Summer roads extending into the mountainous areas are used principally for logging, forest fire control, and access to recreation areas. Since the railroad and highway systems lie generally in the valleys, major floods disrupt transportation and communications.

Land Use

Approximately two-thirds of the subregion is forest land, of which 5 million acres are commercial timberlands and more than 300,000 acres are forest lands which have either been withdrawn from commercial use for recreational and other purposes or are incapable of producing commercial timber. Croplands amount to nearly 1.5 million acres and include nearly all of the bottom lands, low terraces, and foothills. More than one-third of the croplands consist of high quality alluvial bottom lands which are intensively used for specialized agricultural crops. More than 240,000 acres of croplands are irrigated. Rangelands, generally in small parcels among crop and timberlands along the edges of the valleys, amount to 59,000 acres. Urban, industrial, and miscellaneous lands including water areas amount to 922,000 acres.

Streams

The Willamette River is formed by the confluence of its Coast and Middle Forks about 2 miles upstream from Eugene. From Eugene it meanders northward about 160 miles without falls or rapids until it reaches the basalt reef which impedes the river and forms the Willamette Falls at Oregon City. Downstream from Eugene, it is fed by three major tributaries, the McKenzie, Santiam, and Clackamas Rivers, which flow westerly from the Cascade Range; 10 lesser tributaries which originate in the Cascade foothills and Coast Range; and numerous minor creeks. Another major stream in the subregion, the Sandy River, drains from the high Cascade area directly into the Columbia River. The summer flows of the streams which drain the high Cascade area are sustained by snow-melt and ground water from porous volcanic formations, but flows

Table 89 - Streamflow Summary, Subregion 9

Stream	Total Drainage Area (Sq. Mi.)	Gage	Gage Drainage Area	Mean Flow ^{1/} (cfs)	Momentary Flow ^{2/}	
					Max. (cfs)	Min. (cfs)
Sandy R.	510	Bull Run	440	2,302	84,400	45
M. F. Willamette R.	1,354	Jasper	1,340	3,916	94,000	366
C. F. Willamette R.	665	Goshen	642	1,512	58,500	36
McKenzie R.	1,342	Coburg	1,337	5,508	88,200	1 080
Long Tom R.	410	Monroe	391	770	19,300	0
Marys R.	299	Philomath	159	441	13,600	0.6
Calapooia R.	374	Holley	105	438	12,600	18
Santiam R.	1,827	Jefferson	1,790	7,596	197,000	260
Luckiamute R.	310	Suver	240	903	32,900	0.6
Yamhill R.	769	Whiteson	502	1,611	47,200	8.5
Molalla R.	878	Canby	323	1,135	43,600	20
Tualatin R.	712	West Linn	710	1,443	29,300	10
Clackamas R.	937	Estacada	671	2,674	86,900	50
Willamette R.	11,200	Oregon City	10,008	29,900	348,000 ^{3/}	2,470 ^{3/}

^{1/} Regulated values for base period (1929-58) with estimated 1970 conditions of development.

^{2/} Maximum and minimum observed instantaneous values for period of record.

^{3/} Measured at Salem.

in the Coast Range and lowland streams drop off rapidly during the summer dry season. Table 89 lists annual and momentary flows for the most important streams in the subregion; additional information is contained in Appendix V.

Flood Characteristics

Major basinwide floods generally occur from November through February; however, floods may occur as early as October or as late as the end of April. Floods result from intense rainfall usually augmented by melting snow. In the headwaters, runoff follows the rainfall by a few hours and floods crest on the lower Willamette River usually about 3 days after the period of maximum precipitation. Generally, without considering the effects of flood control reservoirs, a flood wave on Willamette River travels from Eugene to Albany in 30 hours, from Albany to Salem in 12 hours, and from Salem to Portland in 35 hours.

The flood of December 1964 (4) illustrates the causes and characteristics of floods of major or catastrophic proportions. It resulted from a combination of all factors that produce winter floods or contribute to flood intensity. The sequence of events preceding the flood began with periods of normal to moderately heavy precipitation for about 1 month before the flood, which practically saturated the ground. On December 14, 5 days before the storm, a strong flow of cold continental air over the Pacific Northwest produced subfreezing temperatures and froze the ground. On the 18th warm, moist, maritime air moving in from the Pacific Ocean was carried aloft by the cold air, and snow fell over much of the Columbia-North Pacific Region; record snowfalls for that time of the year occurred in many places. The flow of maritime air then displaced the cold air. Temperatures along the valley floor reached the high 50's, the freezing level rose to 10,000 feet over Salem, and unusually intense, warm rain fell on the 21st and 22nd. The combination of warm rain, snow on the ground, and the frozen, saturated soil produced the flood; the most important single factor was the heavy rain.

Streams responded quickly to the intense precipitation on December 21 and 22. Most of the tributaries crested on the 22nd or 23rd and were back with banks by the 29th. The Willamette River crested at Albany at 7 a.m. on the 24th; at Salem at 4 p.m. on the 23rd, and at Portland between 8 and 10 a.m. on the 25th; it remained above major flood stage at Salem 4 days. Although

Salem lies farther downstream, the crest occurred earlier there than at Albany, primarily because of the influence of the then uncontrolled South Santiam River.

Floods result even when some of the weather phenomena described above do not occur. Much less severe conditions cause flooding along several of the minor tributaries where gradients are slight and the channels are choked with brush and debris. During late spring or early summer, melting snow in the Cascade Range sometimes causes high water on the Willamette and east-side tributaries.

Ice gorges are not a factor in Subregion 9 floods, but logs and debris have created similar effects, particularly on the smaller streams. Logs and debris carried by floodwaters also aggravate bank-erosion along the Willamette River and the larger tributaries.

During May, June, or July, backwater from the annual Columbia River freshet causes high stages in the Willamette River downstream from the falls at Oregon City. The highest stages of record in the Portland Harbor resulted from Columbia River floods.

Flooding in tributary areas occurs during the winter period from the same phenomena which cause flooding on the major streams.

HISTORY OF FLOODING

Willamette River Basin

Major floods on the Willamette River and its tributaries, mentioned in the writings of early pioneers, occurred in 1813, 1843, 1844, and 1852. One account of the flood of 1813 states that water entered a cabin on a site near Newberg known to have been at a higher elevation than that reached by all subsequent floods except those of 1861 and 1890. However, most histories start with the flood of 1861, which is the earliest known basin-wide flood for which even limited data are available. (7)

The 1861 flood reached a stage of 47 feet ^{1/} and had an estimated peak discharge of 500,000 cfs at Salem. The historic settlement of Champoege was about 63 feet above normal low-water level. Except for two saloons, the town was completely destroyed.

^{1/} Stage at Salem referenced to the present gage.

The small towns of Orelans, across the river from Corvallis, and Linn City, across from Oregon City, also were destroyed.

The 1861 flood inundated about 513,000 acres of the valley floor and caused damages in excess of \$1 million based on development and price levels current at that time. Ten lives are known to have been lost.

Another major flood occurred in 1890. That flood was only slightly less magnitude than that of 1861 and, until 1964, was the second greatest known flood in the basin. Total damages were not recorded, but, considering the economic development in the area at that time, probably amounted to several million dollars. Three deaths were listed as definitely caused by the flood.



Flooding at Portland, Oregon, February 5, 1890. (USCE)

The second greatest flood in order of discharge of floodwaters, and clearly the most devastating and costly flood in the history of the subregion, occurred in December 1964. (4) That flood caused damages in excess of \$70 million even though reservoirs and other flood control works prevented in the order of \$470 million in damages in Subregion 9 and \$40 million in damages to Subregion 8. Four lives were lost due to flood-related causes. Stages on a majority of uncontrolled streams and on tributaries upstream from the reservoirs were higher than had been recorded previously. The peak stage and discharge of the Willamette River at Salem were 37.8 feet and 309,000 cfs, respectively. It is

estimated that the natural stage and discharge, without regulation by storage reservoirs, would have been 45.3 feet and 472,000 cfs; stages at all points on the Willamette River would have exceeded those of 1890 and would have been equal to or only slightly lower than those of 1861.

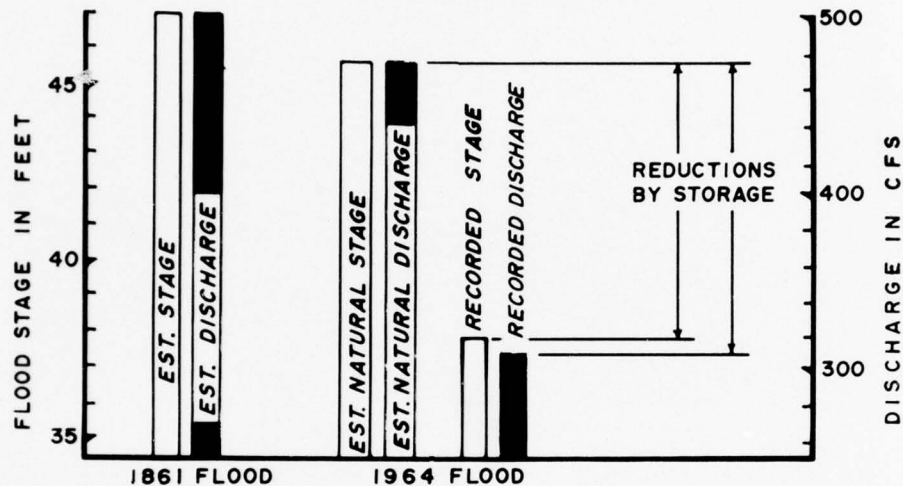


Figure 23. A Comparison of Two Major Floods at Salem, Oregon, Illustrating the Effect of Flood Control Projects.

The Portland reach of the Willamette River, from Oregon City to the confluence with the Columbia River, generally receives its greatest flood damages from backwater of the Columbia River during the annual spring freshet of that river. The floods of June 1894 and June 1948, described under Subregion 8, were the most severe along that reach. However, the coincidental winter flood on the Columbia River when the Willamette River was flooding in December 1964 posed a special threat to Portland. Without reservoir control, principally in the Willamette Basin, that flood would have exceeded the stages of both the 1894 and 1948 floods, and the combination of velocities and high stages would have caused tremendous damages, particularly to the downtown business district and to bridges across the Willamette River.

Less destructive floods have occurred every 5 to 10 years, but because the greatest intensities have occurred in different parts of the basin, those floods have not been classified as major basinwide floods. Since 1900, floods in that category occurred in 1901, 1903, 1907, 1909, 1923, 1927, 1943, 1945, 1953, 1955, 1961, and 1965. In general, storms that cause major flooding in any portion of the subregion produce significant flooding throughout the subregion.



The 1964 flood would have caused tremendous damage through the city of Portland without flood control. (USCE)

Flood damages were surveyed in detail following the floods of 1927, 1943, 1945, 1955, and 1964. Pertinent data from those surveys are presented in table 90; the data in that table are not

Table 90 - Urban and Agricultural Flood Damages,
Subregion 9

Month and year of flood	Agricultural 1/ Area Flooded, (Acres)	Total Damages 2/ (\$)	Total Prevented 2/ (\$)	Lives Lost 3/
Feb 1927	302,000	4,161,000	-	Not available
Jan 1943	342,000	34,000,000	4/	10
Dec 1945	368,000	24,600,000	4/	7
Dec 1955	200,000	15,200,000	13,600,000	2
Dec 1964	211,000	70,749,000	473,436,000 5/	4

1/ Urban and total areas flooded not available.

2/ Existing development and price levels at time of flood; includes Sandy River.

3/ Drowning and flood-related causes; includes Sandy River.

4/ Total damages prevented in the 1943 and 1945 floods were \$2 million, but no breakdown is available as to amount in each flood.

5/ Total damages prevented in Willamette Basin by structural and nonstructural measures. Does not include \$40,400,000 in damages prevented along Lower Columbia River by Willamette Basin Project.

indicative of the comparative magnitude of the floods because of changing developmental and price levels, the variant areas where the flooding was concentrated, and increasing degrees of protection by flood control works during the period from 1943 to 1964.

Sandy River Basin

Before December 1964, when its greatest flood of record occurred, the Sandy River was not considered to have a serious flood problem. (4) That flood caused more than \$5.5 million in damages and the loss of one life. Peak flows were 84,000 cfs downstream from the confluence with Bull Run River and 61,400 cfs near Marmot, as compared with previous recorded peaks of 58,500 cfs in 1931 and 29,200 cfs in 1923, respectively. Damages were associated more often with the velocity of water than with the depth or extent of flooding. Almost all damages occurred on the Sandy River upstream from Marmot and on the principal tributaries in that area, the Salmon and Zigzag Rivers, and Still Creek. In the drainage areas upstream from Marmot, the stream gradients are very steep and the bottoms of canyons are covered with gravel and silt. In the 1964 flood, stream channels were shifted as much as several hundred feet, and the topsoil and vegetative cover were swept away, leaving behind a broad expanse of barren gravel, cobbles, and boulders. More than 150 homes were completely destroyed and many more severely damaged.

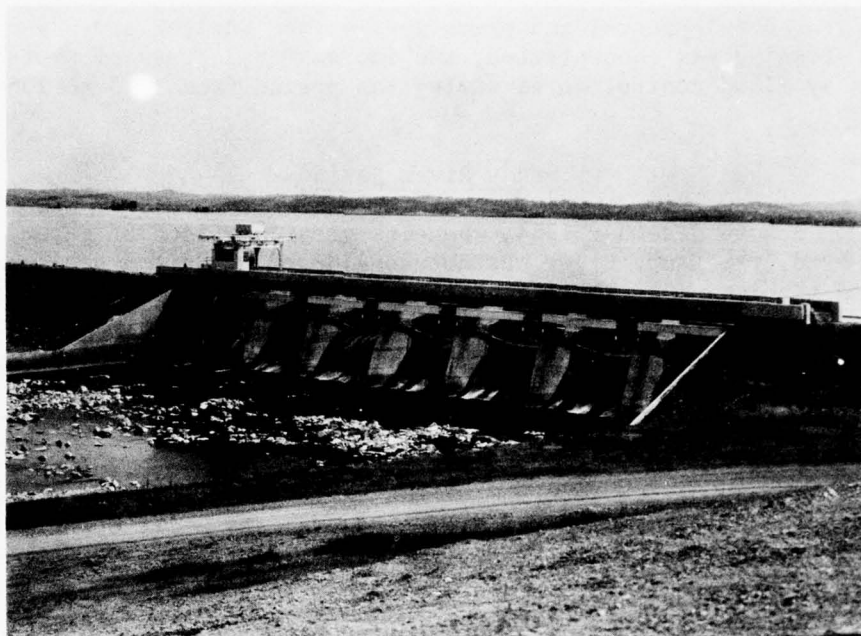
PRESENT STATUS

Existing Measures

Flood Control Storage

Multiple-purpose reservoirs which are a principal element of the Willamette Basin Project provide an aggregate 1,810,300 acre-feet of storage for flood control (table 91). Most of those reservoirs effectively control, at the damsites, floods equivalent to either the 1861 or 1964 floods. The existing storage system controls runoff from about 75 percent of the drainage area upstream from Eugene, 45 percent of the areas upstream from Albany and Salem, and 30 percent of the total area of Willamette Basin. There is no storage for flood control on the Sandy River.

Some flood damages are prevented by farm ponds and reservoirs constructed for other purposes by providing increased usability of land subject to frequent flooding. Aggregate capacity of the subregion's 3,300 farm ponds is 16,500 acre-feet, but such projects have little effect on major floods.



Fern Ridge Dam and Lake, one of the earliest multiple purpose storage projects in the Willamette Basin. (USCE)

Table 91 - Multiple-Purpose Reservoirs with a Flood Control Function, Subregion 9

<u>Reservoir</u>	<u>Stream</u>	<u>Drainage Area</u> (Sq. Mi.) ^{1/}	<u>In-Service Year</u> <u>for Flood Control</u>	<u>Total Flood Control Storage</u> (1,000 ac.-ft.)
Blue River	Blue River	88	1968	85.0
Cottage Grove	Coast Fork Willamette River	104	1942	45.0 ^{2/}
Cougar	South Fork McKenzie River	208	1963	155.0
Detroit	North Santiam River	438	1953	317.9 ^{2/}
Dorena	Row River	265	1949	123.5 ^{2/}
Fall Creek	Fall Creek	184	1965	115.0
Fern Ridge	Long Tom River	275	1941	110.0
Foster	South Santiam River	494	1967	30.0
Green Peter	Middle Santiam River	(277)	1967	270.0
Hills Creek	Middle Fork Willamette River	(389)	1961	200.0
Lookout Point	Middle Fork Willamette River	991	1953	358.9 ^{2/}
Totals		3,047	-	1,810.3

^{1/} Areas shown in parentheses are included in drainage area of a downstream reservoir.

^{2/} Includes surcharge storage.

In the Willamette Basin Comprehensive Study (2), in which the plan for Subregion 9 was formulated, projects that were authorized or considered assured were treated as existing in evaluating the present situation. Separate studies were not made for Columbia-North Pacific. Reservoirs in this category are shown in table 92.

Table 92 - Authorized and Assured Storage Projects, Subregion 9

<u>Reservoir</u>	<u>Stream</u>	<u>Flood Control Storage</u> (Acre-Feet)
Cascadia	South Santiam	145,000
Gate Creek	Gate Creek (McKenzie R.)	50,000
Holley	Calapooia River	90,000
Scoggins	Scoggins Cr. (Tualatin R.)	20,300
McKay Cr.	McKay Cr. (Tualatin R.)	7,000
Rock Cr.	Rock Cr. (Tualatin R.)	5,700

Levees, Revetment, and Channels

Federal, State, and local agencies have constructed local protection projects at 99 locations along Willamette River, 117 locations along principal tributaries, and 33 locations along minor tributaries. The work along major streams (generally those with drainage areas exceeding 400 square miles) includes about 90 miles of revetments, drift barriers, channel closures, and levees, and 13 miles of channel improvements. Similar improvements along minor tributaries total 25 miles of revetments and similar works and 355 miles of stream channel improvement. Of the latter, complete channel rectification is provided for 1.2 miles in Salmon Creek at Oakridge, 7.8 miles in Amazon Creek through Eugene, and 23.5 miles in the Long Tom River downstream from Fern Ridge Dam.

Watershed Protection

In Subregion 9, effective combinations of practices which reduce erosion and sedimentation and assist in the reduction of floods have been put into effect on more than 902,000 acres of cropland. The most effective practices include conservation cropping systems on 555,000 acres, crop residue use on 382,000 acres, and drainage conduits or ditches totaling 7,167 miles in length.

Forest land treatment practices designed to reduce sediment and downstream floodflows include seeding and gully stabilization on 7,100 acres of eroding forest land and rehabilitation of 1,150 miles of roads and trails.

Rangeland practices particularly significant in reducing erosion and sediment and aiding in flow reductions include grass seeding on about 800 acres and brush control on 20,000 acres.

Along minor tributary streams, various structural measures have been taken to alleviate flood problems. The total work accomplished is shown in the following tabulation:

105 miles of levees
 704 miles of stream channel improvement
 321 miles of streambank protection
 13 miscellaneous other stream structures

The soils of the subregion have an estimated water-holding capacity of at least 4.27 million acre-feet, an average of 6.74 inches over the entire watershed. With proper land treatment and under ideal climatic conditions, this storage would be useful in controlling or retarding runoff. Additional information on land treatment is contained in Appendix VIII.

Flood Forecasting

Flood warnings are issued by the National Weather Service for 20 key stations on the larger streams and tributaries. Table 93 shows the key river locations, the flood stage at each, and corresponding discharge. The National Weather Service, Portland River District Office is responsible for the flood warning program.

Table 93 - Flood Warning Locations, Subregion 9

<u>Location</u>	<u>Stream</u>	<u>Flood Stage (Feet)</u>	<u>Discharge (Cfs)</u>
Eugene	Willamette	23	53,800
Harrisburg	Willamette	12	73,200
Corvallis	Willamette	20	88,600
Albany	Willamette	25	91,000
Salem	Willamette	28	154,000
Wilsonville	Willamette	25	135,000
Oregon City (Upper)	Willamette	14	197,000
Oregon City (Lower)	Willamette	27	1/
Portland	Willamette	18	1/
Coburg	McKenzie	11	35,700
Philomath	Marys	20	5,820
Jefferson	Santiam	15	46,000
Suver	Luckiamute	27	7,100
Whiteson	South Yamhill	38	13,600
Aurora	Pudding	20	4,940
Canby	Molalla	13	24,000
Dilley	Tualatin	17	3,300
Farmington	Tualatin	29	7,760
Sycamore	Johnson Creek	8	730

1/ Rating curve affected by backwater of Columbia River.

In this appendix, those lands in the subregion lying along Columbia River are included with the presentation for Subregion 8

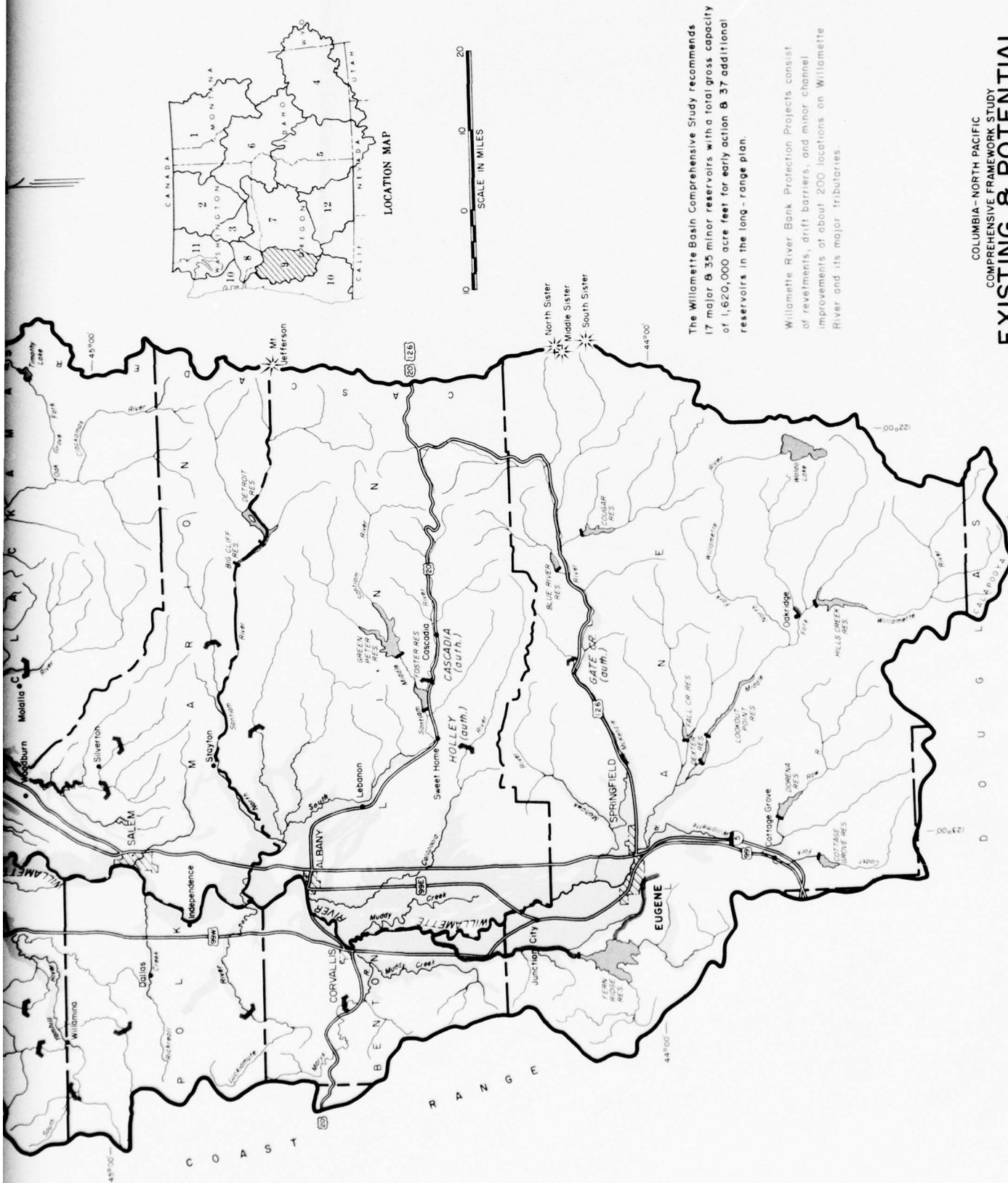


EXPLANATION
 FLOOD SUSCEPTIBLE AREAS
 POTENTIAL STORAGE SITES
 EXISTING LEVEES AND CHANNELS
 POTENTIAL



LOCATION MAP

SCALE IN MILES
 0 10 20



Base Rev Oct 1969

The Willamette Basin Comprehensive Study recommends 17 major & 35 minor reservoirs with a total gross capacity of 1,620,000 acre feet for early action & 37 additional reservoirs in the long-range plan.

Willamette River Bank Protection Projects consist of revetments, drift barriers, and minor channel improvements at about 200 locations on Willamette River and its major tributaries.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY
**EXISTING & POTENTIAL
FLOOD CONTROL FACILITIES**
WILLAMETTE SUBREGION 9

1970

FIGURE 24

Flood warnings are issued when near-bankfull stages, which are generally from 1 to 5 feet below actual flood stages, are expected. When flood stages are reached, forecasts are issued at 12-hour intervals or more frequently if weather conditions change radically. Forecasts are continued until streams recede to below-bankfull stages and all danger has passed.

Close cooperation is maintained with State, county, and city authorities; Federal agencies; Civil Defense officials; private and public utilities; and the news media (radio, television, and newspapers). Dissemination methods used in various places may include radio and television announcements, sirens, loudspeaker trucks and aircraft, or door-to-door patrols by Civil Defense workers or policemen.

Flood Plain Use Regulation

Interim flood plain information reports have been prepared for Benton, Clackamas, Linn, Marion, and Yamhill Counties, showing the limits of flooding by some of the recent major floods on the Willamette River. Detailed reports have been prepared to show the areas inundated by various sizes of floods in Lane, Marion, Polk, Clackamas, and Washington Counties; work is in progress on a report for Benton County. These reports furnish local governments information as a basis for flood-plain-use regulations.

Local governments are permitted by Oregon law to enact zoning ordinances for control of development in the flood plains. Lane, Linn, Washington, and Yamhill Counties have drafted or adopted such ordinances.

Accomplishments

Storage

An evaluation of the flood damages along Willamette River and tributaries was made following the flood of December 1964. Stage reductions which were realized from flood control storage then existing, and those which can be accomplished by storage presently available (see table 91) are listed in table 94.

With completion of all authorized reservoirs in the Willamette Basin, which will provide an aggregate flood control storage of about 2,000,000 acre-feet, the total area inundated by a flood such as occurred in 1861 will be reduced from an estimated 513,000 to 330,000 acres. Through July 1965, flood control in the Willamette Basin had prevented cumulative total damages

Table 94 - Stage Reduction of December 1964 Flood by Storage
Reservoirs, Subregion 9

Place	Estimated Natural Stage (ft.)	Observed Stage (ft.)	Reduction	
			With Storage Available Dec. 1964 (ft.)	With 1970 Storage (ft.)
Eugene	39.0	24.2	14.8	15.6
Albany	35.2	28.9	6.3	7.8
Salem	45.3	37.8	7.5	11.2
Oregon City (Upper)	23.3	19.9	3.4	4.6
Portland	34.4	29.9	4.5	5.5

estimated at \$594 million, of which \$509 million including \$40 million along the lower Columbia River were prevented during the 1964-65 flood season.

Under present conditions of development within the flood plain, but with no prevention measures, average annual damages would be \$27.9 million (1965 prices and development). With the existing control and assuming the authorized reservoirs complete, the residual average annual damages, based on the same conditions and price levels, would be reduced to about \$5.4 million.

Levees, Revetments, Channels

Levees and revetments were credited with having prevented 20 to 30 major avulsions and channel changes during the 1964 flood. Channel improvements on Amazon Creek through Eugene and on Salmon Creek through Oakridge prevented damages which would have amounted to \$750,000. Damages prevented by the completed revetments and channel improvement work during all previous floods are estimated to be \$18 million. Projects along minor tributaries have been credited with total flood damages prevented of about \$4.9 million through July 1965; \$4 million of that total were prevented in the December 1964-January 1965 floods. Levees, revetments, and channels are credited with reducing the average annual damages in the basin by \$0.8 million.

Seven comprehensive watershed projects comprising flood control structures and land treatment reduce the extent of flooding on 10,000 acres of largely agricultural lands within the watersheds. Average annual flood damages on these lands are reduced by \$529,000.

Remaining Flood Problems

Inundation

Major flood problems in Willamette River Basin result from inundation of lands and developments in areas either unprotected or only partially protected by existing storage reservoirs. Damages are intensified by improper land use in upland areas and occupancy of inadequately protected portions of the flood plain.

Areas Flooded

The areas of the Willamette River Basin flood plain may be classified in three categories, according to the degree of inundation. In the first category are low-lying lands which are inundated by minor floods, when streams in many locations flow just over bankfull.

The second category includes areas that are affected by the major floods that recur at 10- to 100-year intervals, and the third category consists of lands that are flooded only by extremely rare catastrophic floods, which would approximate the 1964 flood without control.

Lands of the first category, consisting of approximately 50,000 to 100,000 acres, may not be severely damaged during any one flood, but the frequent flooding prevents full development. Those lands generally are allowed to be overgrown with brush and moisture-loving trees, and sometimes are used for pasture or crops that provide cover through the winter months.

The lands of the second category total 330,000 acres, including some 50,000 acres of developed industrial, commercial, and residential lands and 280,000 acres of farmland. Much of the area, especially along the Willamette River, has been taken from the first category into the second, or less frequently flooding category by flood control storage and other measures. Most of the reservoirs of the Willamette Basin Project control floods up to 100-year frequency at the damsite, but floods of damaging proportions form in uncontrolled drainages and downstream from the reservoirs. Development on the lands now protected has greatly accelerated since flood control storage has been provided. Intensive farming is practiced on lands of the flood plain areas in the second category. In many places where the land is suitable, it has been cleared to the riverbank. Without a protective fringe of brush and trees, the land is vulnerable to surface erosion and deposition of debris, weed seed, and silt. The force of floodwaters upsets trees and bares the roots of many perennials. In

some areas silt is deposited in drifts which must be removed to allow the land to be cropped.

Second category areas include, in the Eugene-Springfield area, the flood plain of the McKenzie River along the northerly edge of Springfield, the area between the McKenzie and Willamette riverbanks, and a few low-lying areas through the city of Eugene. The Springfield second category area varies up to almost a mile in width. It is intensely farmed with orchard, row, and field crops but contains little residential or commercial development. Downstream from the city of Eugene, the Willamette River is affected by backwater from the McKenzie River and during flooding periods spreads out to cover several hundred acres of farmland and several suburban housing tracts.



Left bank of Santiam River during 1964 flood. (USCE)

From Eugene to Salem, the width of the flood plain varies from 1 to 3 miles (figure 10). Lands are devoted mostly to agriculture and are highly developed except in the low-lying areas which are frequently flooded. Buildings are located generally on higher ground out of immediate flood danger but suburban-type developments are in the flood plain in the vicinities of Junction City, Corvallis, Albany, and Independence.

In the Salem area, the flood plain contains more than 350 homes, extensive commercial and industrial developments, the

city's sewage treatment plant, several marinas and moorages, and a recently completed modern hospital. Much of this development is on lands formerly flooded at frequent intervals but now protected by flood control storage and flooded only by major floods.

Between Salem and Oregon City, most of the flood plain is agricultural land.

The flood plain area of Oregon City and downstream to the mouth of the Willamette River includes the papermills at Willamette Falls, a shopping center at Oregon City and an adjacent partially developed industrial residential area, an industrial park at Lake Oswego, and the industrial areas between the Sellwood and Hawthorne Bridges in Portland. The banks of the Willamette River from Oregon City to the Portland city limits are occupied by attractive homes with park-like grounds. Generally, the developments are above all except major flood levels, but damages occur regularly to boathouses, landscaping, and recreational facilities. Major floods damage the houses.

Still included in the third flood-plain category would be 330,000 acres of the 513,000 acres that were flooded in 1861. Approximately 180,000 acres are protected from flooding similar to that of 1861 by the Willamette River Basin Project multiple-purpose reservoirs. On the basis of infrequent flooding, those 180,000 acres might not be considered an important part of the flood plain. However, an important consideration is the very high degree of development on much of those lands, and the risk to occupants through an attitude of indifference or ignorance of danger. In the Eugene-Springfield area a flood which substantially exceeded the capacity of the reservoirs would damage the sawmills and much of the residential development. Such a flood would also inundate a part of the business district and about 1,300 acres of residential development in Salem. From Salem to Oregon City development of the flood plain is principally agricultural. Most other development is on higher ground and not damaged by floods.

A flood equivalent to that of 1861 or 1964 uncontrolled would cause catastrophic damages throughout 430 acres in the main business and industrial districts of the city of Portland, including its entire waterfront and railroad terminals and switchyard. It would also destroy or severely damage the water and sewage facilities of nearly every city in the valley and cripple highway transportation. The importance of this portion of the flood plain is shown by the fact that damages prevented during the 1964 flood included nearly \$375 million in the Portland area alone. Assuming normal continued development in the flood plain, by the year 2000 damages from such a flood could amount to more than a billion dollars.

Small Tributary Streams

Flooding in the tributary areas usually occurs during the winter from the same prolonged heavy rains (sometimes with snow-melt) which causes flooding on the major streams. Areas flooded comprise 8,000 acres urban and 169,000 acres rural including 120,000 acres of cropland. Average annual damages in these areas amount to \$292,000 urban and \$808,000 rural. These damages are included in the basin and subregion totals shown in table 96.

Streambank Erosion

There are an estimated 2,100 miles of streambank subject to erosion, of which 540 miles can be considered severe. These figures include those presented for small tributaries in the previous paragraph. Present average annual erosion damages are shown in the following tabulation. These damages are included in the basin and subregion totals shown in table 96.

<u>Land Loss</u>	\$513,900
Urban	(127,100)
Rural	(386,800)
<u>Sedimentation</u>	571,800
<u>Other</u>	80,600
TOTAL	\$1,166,300

PROJECTIONS AND NEEDS

Economic Trends

The population of Subregion 9 is expected to grow at a faster rate than that of the region. From a 1965 population of 1,339,000, OBERS projections are for populations of 1,727,000 in 1980, 2,398,000 in 2000, and 3,237,000 by 2020, which represents an average growth rate of about 1.7 percent annually over the 60-year period. Corresponding figures given in the Willamette Basin Comprehensive Study, which developed the plan adopted by the Columbia-North Pacific Study, are 1,339,000 in 1965, 1,768,000 in 1980, 2,422,000 in 2000, 3,591,000 in 2020, and an average growth rate of 1.8 percent annually. Most of the growth is expected to occur in the Portland, Salem, Albany-Corvallis, and Eugene-Springfield areas.

Agricultural production is expected to increase significantly; however, agricultural employment will decline because of improving technology, increasing yields, better labor utilization, and greater capital investment per worker. Increased output is envisioned in many manufacturing industries. Growth in employment is expected to occur in the chemical and allied products industries, in the primary metals industries (both ferrous and non-ferrous), in nonresource based manufacturing, and in the residential industries. The subregion is developing a diversified and expanding complex of manufacturing industries and provides numerous residential services for much of Oregon and southern Washington.

Basic population, employment, and income data, as projected by OBERS and the Willamette Basin Comprehensive Study (2) are shown in table 95.

Table 95 - Population, Employment, and Income, Subregion 9

	OBERS				Willamette Basin Comprehensive 1/			
	Base	1980	2000	2020	Base	1980	2000	2020
Total Population (1,000)	1,339	1,727	2,399	3,237	1,339	1,768	2,422	3,591
Total Employment (1,000)	431	680	949	1,280	530	650	881	1,303
Ag & Food Proc. (1,000)	35	30	28	24	42	31	26	23
Paper & wood prod. (1,000)	37	31	27	24	40	33	26	23
Per Capita Income (\$1)	2,328	4,175	7,096	12,287	2,357	3,665	5,665	8,700
Total Personal Income (\$1 million)	2,835	7,212	17,012	39,775	2,792	6,478	13,720	31,240

1/ Adopted by Columbia-North Pacific

The basic differences between the two projections are that the Willamette shows greater increases in population and employment whereas the OBERS shows greater increases in per capita and total personal income. Additional information on population and economic projections is shown in Appendix VI, Economic Base and Projections.

Flood plain lands have been subjected to much more intensive use in recent years. Riverside property is in great demand for homesite development and for other uses. The control of floods by upstream storage is accelerating such development. There also has been a steady increase in land returns due to improved agricultural technology--better fertilizer programs; improved methods of controlling pests, weeds, and disease; improved varieties of many crops; more efficient irrigation; and similar advances. Department of Agriculture studies indicate that increased productivity due to these factors amounts to from 2 to 4 percent

annually. There is reason to consider that such improvement will continue.

New urban development is expected to occur in the Portland, Eugene-Springfield, Salem, and Albany-Corvallis areas and along the remaining portions of Willamette River and the downstream reaches of the major tributaries. In the absence of regulatory action, much of that development would be in the flood plain. Because of present and future transportation facilities, business patterns and other locational advantages, industrial development will continue on flood plain lands.

Future Flood Damages

In the Willamette Basin Comprehensive Study, agricultural, community, and industrial damages were projected for each major tributary or composite subbasin and each distinct reach of Willamette River. Local area growth rates were assumed from projections of crop yields, normal shifts to higher land uses, and projections of population, income, and industrial productivity. The detailed projections resulted in composite growths of about 2 percent for agriculture, slightly over 4 percent for community, and nearly 5 percent for industrial damages. Total damages as shown in the Willamette study, based on 1965 prices and development and all existing and authorized flood control structural measures, are shown in table 96. These damages also include equivalent average annual damages in small watershed areas and the dredging necessary to maintain the navigation channels in the Willamette and Columbia Rivers to the extent such work is caused by flooding of Willamette River. Additional details are included in Appendix E, Flood Control, of the Willamette Basin Comprehensive Study.

Detailed projections were not made for the Columbia-North Pacific Study. A comparison of the economic growth parameters and projected agricultural productivity used in the Willamette Basin Study with those developed by OBERS for the Columbia-North Pacific Study indicated that no significant change in future damage levels would result. Further, since the framework plan for Subregion 9 was to be taken from the Type II study, no useful purpose would be served by a separate projection of future flood damages.

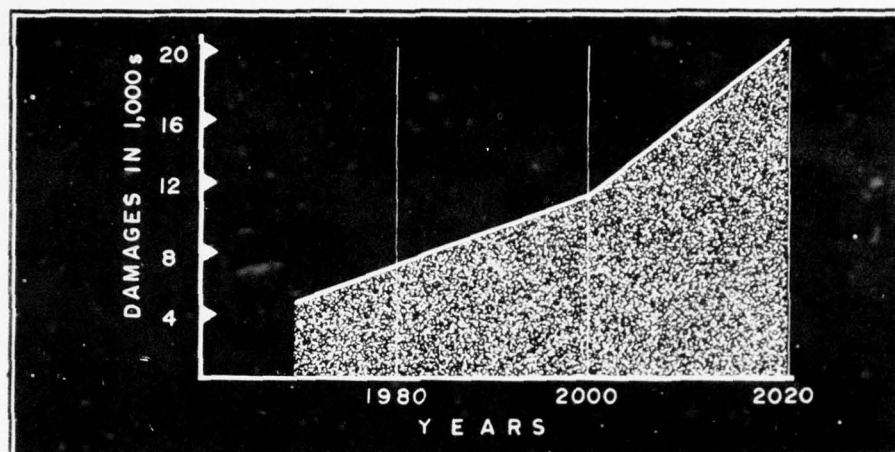


Figure 25. Projected Average Annual Flood Damages, Subregion 9.

Table 96 - Present and Projected Average Annual Damages,
Subregion 9 1/

Stream Basin	Average Annual Flood Damages in \$1,000 1965 Price Levels 1/					
	With 1965 Economic Development			With Projected Economic Development		
	Rural	Urban	Total	1980	2000	2020
Coast Fork	68	137	205	241	332	529
Middle Fork	12	207	219	255	344	540
McKenzie	22	320	342	381	466	654
Long Tom	112	209	321	452	766	1,450
Santiam	507	503	1,010	1,160	1,447	1,956
Coast Range	390	342	732	874	1,162	1,713
Pudding	363	174	537	703	1,031	1,643
Tualatin	489	131	620	670	932	1,594
Clackamas	14	416	430	617	1,113	2,291
Columbia	8	125	133	241	550	1,338
Sandy	0	36	36	65	155	413
Main River	440	430	870	1,410	2,800	6,230
Total	2,425	3,030	5,455	7,069	11,098	20,351

Source: Willamette Basin Comprehensive Study

1/ All data include streambank erosion and damages in small tributary areas.

MEASURES REQUIRED TO SATISFY FUTURE NEEDS

Storage

The total amount of additional upstream storage to control flooding in Subregion 9 has not been determined. Amounts to control 100-year frequency floods to bankfull stages at various locations throughout the subregion are shown in table 97. These amounts are not inclusive. For example, provision of the 98,500 acre-feet needed to control the Coast Fork and the 355,000 acre-feet to control the McKenzie would not completely satisfy the need for 410,000 acre-feet to control the Willamette River at Harrisburg. Furthermore, the table does not include all drainage areas. Incomplete as it is, the table of additional storage requirements represents a much higher degree of control than can ever be achieved considering the availability of suitably located reservoir sites.



Houses afloat during 1964 flood at Kaiser, a suburb of Salem, Oregon. (USCE)

In the Willamette Basin Comprehensive Multi-Agency Study (2), a preliminary plan of development has been formulated. The plan is based on an existing situation that comprises not only the existing projects, but also six new projects, table 92, that are either authorized for Federal construction or considered to be assured. The early action phase of the plan calls for

construction of fifty additional reservoirs of which thirty would have assigned flood control or joint use space totalling nearly 800,000 acre-feet and three would provide incidental control of floodwaters. Total costs would be \$285 million for the thirty projects with an assigned flood control function and \$3.5 million for the three with incidental service. The long-range phase calls for thirty-seven additional reservoirs of which thirty or thirty-three, depending on operational determinations, would provide approximately 500,000 acre-feet of flood control storage at a cost of \$170 to \$185 million.

Table 97 - Additional Storage Required to Control 100-Year Flood to the Regulation Goal at the Stations Shown, Subregion 9

Stream	Station	Drainage Area (Sq. Mi.)	Bankfull Capacity (Cfs) 1/	Regulation Goal (Cfs) 2/	Additional Storage Required 3/ (Ac-ft)
Coast Fork Willamette River	Goshen	642	9,000	12,000	98,500
Middle Fork Willamette River	Jasper	1,340	16,000	20,000	-
Willamette River	Eugene	2,030	40,000	40,000	12,000
McKenzie River	Coburg	1,537	23,000	24,000	352,000
Willamette River	Harrisburg	3,420	40,000	45,000	410,000
Long Tom River	Monroe	591	5,400	6,000	35,500
Marys River	Philomath	159	2,900	3,000	50,000
Calapooia River	Albany	372	5,500	5,500	54,000
Willamette River	Albany	4,840	55,000	60,000	660,000
South Santiam River	Waterloo	640	18,000	18,000	20,000
North Santiam River	Mehama	655	17,000	17,000	60,000
Santiam River	Jefferson	1,790	32,000	35,000	205,000
Luckiamute River	Suver	240	5,000	5,000	105,000
Willamette River	Salem	7,280	115,000	100,000	720,000
South Yamhill River	Whiteson	502	11,000	13,000	124,000
Willamette River	Wilsonville	8,400	100,000	115,000	1,523,000
Pudding River	Aurora	479	5,000	5,000	150,000
Molalla River	Canby	523	9,000	12,000	75,000
Tualatin River	West Linn	710	5,500	6,000	281,300
Willamette River	Willamette Falls (Upper)	10,100	140,000	140,000	1,850,000
Clackamas River	Clackamas	936	20,000	22,000	305,000
Willamette River	Portland	11,200	200,000	200,000	900,000
Sandy River	Troutdale	502	20,000	20,000	200,000
Tributary Areas 4/					16,500

1/ As of March 1969.

2/ Regulation goal is the channel capacity which could be made available by minor channel improvements proposed in the comprehensive multiagency report on Willamette River Basin.

3/ For control of 100-year floods, as regulated by existing and presently assured storage projects where appropriate, to the level shown as a regulation goal; the amount of storage, and degree of control which would be economically justified may differ considerably from the figures shown.

4/ Farm ponds and reservoirs.

After completion of the early-action phase, the McKenzie, Clackamas, and Sandy Rivers would remain essentially uncontrolled. Substantial amounts of storage would still be needed in the Coast Fork, Pudding, and Tualatin Basins. The projects in the long-range plan would not control the McKenzie or the Sandy and would leave substantial storage needs for control of the Pudding, Tualatin, and Clackamas.

More detailed discussion of flood control storage measures for Subregion 9 is contained in Appendixes E (Flood Control) and M (Plan Formulation) to the report on the Willamette Basin comprehensive multi-agency study. (2)

Levees

The future demand for levee protection will depend on needs that might become evident after the formulated plan is implemented. Such needs might arise where intensive, localized developments would warrant levee protection. The plan at present contains no provision for levees.

Channel Improvement

Channel clearing, snagging, enlargement, and stabilization are used to provide and maintain increased channel capacity and thus to lower flood stages. In the formulated plan, this type of flood control measure is employed in combination with upstream storage projects. Especially on some smaller tributaries such as Pudding River and Tualatin River, which lack sufficient storage potential to effectively control flooding, channel work is an appropriate measure to achieve a reasonable degree of flood protection. The estimated cost of channel work needed in the sub-region within the next 10-15 years, as formulated in the Willamette Basin Comprehensive Study, is about \$55 million for 170 miles of channel improvement on major streams; after 1980, an additional 115 miles will be needed at a cost of about \$27 million.

On minor streams, about 186 miles of channel improvement will be required in the next 10-15 years at a cost of about \$5.2 million, and an additional 280 miles at an estimated cost of \$7 million after that time.

Channel stabilization, including prevention of bank erosion and control of stream meandering, can be accomplished by construction of revetments as part of a channel improvement project, and by vegetative means. Revetment protection cost would range from \$25,000 to over \$250,000 per mile, depending on whether the work was on a major or minor stream. Concrete retaining walls, which might be required in urban areas, would greatly exceed the costs of revetments. Vegetative measures, which necessarily lend themselves only to smaller streams and headwater areas, would cost about \$8,000 per mile.

Flood Plain Use Regulation

The Willamette Basin Comprehensive Study considered a flood plain use regulation program as a means of preventing unwarranted development in the flood plains. Responsibility for the program would remain with local agencies, but State and Federal agencies would furnish information and guidance. Such a program would

reduce the rate of growth of future industrial and community flood damages but future agricultural damages probably would be increased. The estimated effects of an aggressive regulation program are shown in table 98.

Table 98 - Effect of Flood Plain Use Regulation Program on Future Flood Damages, Subregion 9

Year	Increase in Damages	Decrease in Damages		Total
	Agricultural (\$1,000)	Industrial (\$1,000)	Community (\$1,000)	
1980	100	0	300	200
2000	500	100	1,200	800
2020	1,500	200	3,900	2,700

Forecasting

The greatest opportunity for improvement in forecasting is to predict more accurately the amount of rainfall which will be produced by oncoming storms. Although the flood forecasting system in the subregion is fairly effective, more information on snowpack depth and associated air temperatures and more rapid collection of hydrometeorological data would improve the accuracy of the forecasts. With more data and improved techniques, runoff forecasts could be improved so that existing flood control reservoirs could be operated more effectively. Fairly accurate stage forecasts can be developed for downstream areas because most of the flood-producing rainfall occurs long before the flood peak arrives. However, the flood control reservoirs are located much closer to the source of the runoff, and plans for regulation of the reservoirs are made even before the first floodflow occurs. The prediction of storm rainfall has proven to be a difficult problem, but hopes are held for improvement through the use of weather satellites and other technological developments.

Land Treatment

A combination of improved management practices, land treatment measures, and water control structures will be necessary to satisfy future watershed needs for flood prevention. Water control structures are included in the preceding discussions of storage, levees, channels, etc. Cropland practices that are still needed include 305,000 acres of conservation cropping systems, 210,000 acres of crop residue use, 14,335 miles of conduits and ditches, and 430,000 acres of irrigation water management.

Forest land treatment measures required to reduce sediment and tributary floodflows include 80,400 acres of erosion-control treatment and 2,000 miles of road and trail rehabilitation.

Rangeland practices required to reduce erosion and sediment and to aid in reducing flows include 3,700 acres seeded to grass and 4,000 acres of brush control.

Comprehensive Watershed Treatment

Comprehensive treatment programs comprising land measures and small flood control structures should be applied to 72 watersheds which have a total of 97,800 acres subject to flood damages. The works on these watersheds are included in the preceding discussion of storage, levees, channels, and land treatment.

Additional information on land measures and watershed protection is included in Appendix VIII.



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SUBREGION 10

COASTAL

GENERAL

Subregion 10 consists of the coastal drainages between the California-Oregon border and Cape Flattery at the entrance to the Strait of Juan de Fuca. It includes the drainage basins of all streams, except the Columbia River, in Oregon and Washington which flow directly into the Pacific Ocean, minor drainages that flow into Columbia River estuary, and drainage into the Strait of Juan de Fuca east to, but not including, the Elwha River Basin near Port Angeles. For purposes of the flood-control study, the portion of Subregion 10 in the Columbia River flood plain is included with Subregion 8.

The area is 23,763 square miles of which 17,293 square miles is in Oregon and 6,470 square miles in Washington. It is essentially a narrow strip of land about 450 miles long by 15 to 40 miles wide lying between the Pacific Ocean and the crest of the Olympic and Coast Range Mountains, except that the Chehalis River Basin in Washington and the Rogue and Umpqua River Basins in Oregon extend through to the Cascade Range.

Physiography

Except for the areas in the Chehalis, Rogue, and Umpqua Basins which lie easterly of the Coast Range, Subregion 10 occupies the coastal margin between the Pacific Ocean and the crest of the Coast Range. This coastal margin is dominated throughout the length of the subregion by high mountainous uplands with narrow, deeply entrenched valleys and steep forest covered slopes. In most areas there is an abrupt change to the footslopes, fans, terraces, and bottom lands that occur along the narrow coastal plain and extend inland along the main rivers and tributaries. While much of this lower area is also forested, it contains practically all of the limited cropland and economic development in the coastal margin. In several places, the mountains extend to the ocean and terminate in abrupt headlands which reach from several hundred feet above to 10 to 50 fathoms below sea level.

The coastal margin streams have short steep headwaters and narrow flood plains along their lower reaches.

The interior of the Chehalis Basin occupies a portion of the Willamette-Puget Trough, (see Subregions 9 and 11), and has low, almost indistinguishable divides separating it from the Deschutes and other Puget drainages on the north and the Cowlitz Basin on the south. The Rogue and Umpqua Basins contain large interior valleys located between the Coast and Cascade Ranges. These valleys are again surrounded and broken by mountainous uplands with steep slopes and forest cover, but the forests are less dense and are interspersed with open, grassy, and brushy rangeland. There are gradual transitions from mountain slopes to valley floors, and the lowlands extend to several miles in width.

Climate

The areas of Subregion 10 have two distinctive climates. Along the coastal margin, the climate is moderate and humid. Temperatures near the ocean seldom rise above 90°F. in the summer or drop below 20°F. in the winter. Annual precipitations range from 60 to 110 inches along the coast and increase to as much as 200 inches along the summit of the Coast Range. During the winter months, the prevailing weather is characterized by persistent rainfall. Rain may continue almost uninterrupted for several days, or moderate to heavy rainstorms may produce 4 to 6 inches at the coastal towns in a 24-hour period. Approximately 80 percent of the annual precipitation occurs from October through March. Summer precipitation is generally limited to occasional light rains. Snowfalls vary from a trace near the coast to several feet at about 3,000 feet of elevation, but it is only in the higher elevations of the Olympic Mountains that snow normally remains on the ground through the winter. Snowmelt may augment the runoff from winter rainstorms but is not usually a significant factor in producing flooding, and snowmelt alone does not produce floods.

The climate of the Rogue and Umpqua interior basins is drier and more severe. Annual precipitations range from 20 inches at Medford and Ashland up to 100 inches in the higher mountains. Temperatures as high as 115°F. and as low as -20°F. have been recorded. The average annual snowfall at lower elevations ranges from 10 to 25 inches and increases fairly rapidly with elevation. At Crater Lake National Park Headquarters, at nearly 6,500 foot elevation, the average annual snowfall is 575 inches. Snowmelt has been a significant contributor to all major floods, but snowmelt alone does not normally cause flooding.

Economic Development

The population of the economic subregion (1965 est.) is 405,500, of which approximately 87 percent are located in Oregon and the balance in Washington. The population and economic data for Subregion 10 does not reflect the activities in the upper Chehalis River Basin or along the coast north of the Quinault River. The subregion contains one city with more than 25,000 population, seven with 10,000 to 25,000, and 15 with 2,500 to 10,000. Approximately 40 percent of the population is urban; the rural population includes some 85 towns with population of 250 to 2,500. The economy is centered on forest management and forest-based industries, which together employ nearly 25 percent of the total work force. Other significant economic activities include agriculture, offshore and estuarine fisheries, and the processing of food products. Tourists from outside the subregion contribute significantly to the service industries. All cities and towns are served by all-weather roads, and most of the larger cities by railroads. There are four harbors in addition to Columbia River suitable for deep-draft shipping and 11 suitable for shallow-draft barges or fishing boats.

Streams

The principal streams are listed in table 99. With few exceptions, the general characteristics of all the coastal streams are remarkably similar. Headwater areas are steep, and rock formations are relatively impervious. Streams have steep gradients almost to tidewater, and lands suitable for agriculture are generally limited to small benches adjacent to tidewater and the lower stream reaches. Streams respond quickly to rainfall, and major floods follow 24 to 36 hours of sustained, heavy rain. Such floods are frequently as intense, though of shorter duration, as the floods which follow major regional storms. Summer flows are scant.

The streams which do not fit this pattern include the Rogue, Umpqua, and Coquille in Oregon and the Chehalis in Washington. The Rogue and Umpqua Rivers have substantial interior drainage areas and derive much of their flow from the Cascade Range. These streams have high water almost every year but reach significant flood stages less frequently and only after several days of sustained heavy rainfall usually following a period of moderate rain. See Subregion 9 description of the 1964 flood. Summer flows in the Rogue and North Umpqua Rivers are sustained by snowmelt and good aquifers in the Cascade Range.

Table 99 - Streamflow Summary, Subregion 10

Stream	Total Drainage Area (Sq. Mi.)	Gaging Station		Mean Flow 1/ (cfs)	Momentary Flow 2/	
		Location	Drainage Area (Sq. Mi.)		Max. (cfs)	Min. (cfs)
Chetco	365			4/	4/	4/
Rogue	5,060 3/	Grants Pass	2,459	3,235	152,000	195
Coquille	1,070	Coquille	943	3,129	4/	4/
Coos	420			4/	4/	4/
Umpqua	4,710	Elkton	3,683	7,353	265,000	640
Siuslaw	585			4/	4/	4/
Alsea	353	Tidewater	334	1,545	41,800	45
Yaquina	252			4/	4/	4/
Siletz	340	Siletz	202	1,521	40,800	48
Nestucca	330	Beaver	180	4/	24,000	32
Trask	180	Tillamook	145	4/	23,000	42
Wilson	208	Tillamook	161	1,171	32,100	34
Nehalem	860	Foss	667	2,675	43,200	34
Naselle	133	Naselle	55	425	11,100	19
Willapa	258	Willapa	130	4/	11,400	13
North	252	Raymond	219	941	35,000	21
Chehalis	2,114	Grand Mound	895	2,761	48,400	82
Humptulips	245	Humptulips	130	4/	33,000	82
Quinalt	434	Quinalt Lk.	264	2,766	52,600	276
Queets	449			4/	4/	4/
Hoh	299	Forks	253	1,991	46,000	410
Quillayute	629	Soleduck at Fairholm	84	597	23,500	51

1/ Regulated values for base period, see Appendix V.

2/ Observed flows during period of record.

3/ Includes approximately 150 sq. mi. in California and outside Columbia-North Pacific Region.

4/ Not available.

The characteristics of the Coquille and Chehalis Rivers are similar to the smaller coastal streams, but these rivers drain areas large enough to also produce major floods during regional storms.

Flood Characteristics

Overbank flows occur on most of the coastal streams almost every year and sometimes more than once in a single year. However, most of the developments on lands so flooded are compatible with occasional short-term flooding, and little damages result. More severe floods occur coincident with major regional floods, and severe flooding sometimes occurs in single basins with only minor flooding in adjacent areas. Flooding in the tributary areas results from the same prolonged heavy rains that cause flooding in the main streams and coincides with such flooding. Most flooding is of extremely short duration; streams rarely remain above flood stage for more than 12 to 36 hours. Along the tidal reaches flooding occurs when river floodflows coincide with storm and higher than average tides. Such flooding usually recedes with the tide but may return 12 or 24 hours later on the next high tides. December and January are the months of greatest flood potential, but damaging floods may occur as early as the first of November or as late as the last of April.

The Rogue, Umpqua, Coquille Rivers, and to a lesser extent, the Chehalis do not conform to the above flood patterns. These are larger streams which flood only after more sustained rainfall. Severe floods occur in the Rogue and Umpqua Rivers' interior basins at about 10-year intervals usually resulting from several days' sustained heavy rainfall sometimes augmented by snowmelt. Flooding lasts for 2 or 3 days with peak stages for only a few hours. More damages are done by debris and velocity of flow than by simple inundation. The lower Coquille Basin contains several thousand acres only 2 or 3 feet above sea level, and flow of floodwaters from the basin to the ocean is retarded by a constriction in the valley. As a result, floods as much as a week apart that would be separate events in other streams combine into higher stages than would occur from either flood alone. Severe floods occur on Coquille River when no other nearby stream has more than moderate overbank flow, but major floods usually result from major regional storms. Duration of flooding on the Coquille River is longer than on other coastal streams, and use of the flood plain is hampered by sustained spring wetness.

HISTORY OF FLOODING

Major floods occurred in 1955 on many streams along the Oregon coast, and stages in the lower Coquille Basin were as high as have been reported during historical times. (16) However, most of the Oregon portion of the subregion received its most severe flooding in December 1964. (4) During that flood, previous maximum stages were exceeded on the Wilson, Trask, Yaquina, Alsea, Umpqua, Coos, and Chetco Rivers. Near-record floods were observed on the Necanicum, Nehalem, Nestucca, Siletz, and Rogue Rivers. The main Umpqua River at Elkton exceeded its 1955 peak almost 6 feet, and stages along the lower Umpqua exceeded the reported stages of the historical floods of December 1861 and February 1890. Coquille River reached a peak discharge at Coquille, of 110,000 cfs, and a crest 2.5 feet above major flood stage identical to the crest stage in the December 1955 flood. The flood exceeded the December 1955 flood stage on Rogue River at all gaging stations and was surpassed only by the historical floods of December 1861 and February 1890.

The discharge volumes during the December 1964 flood were so large that the Umpqua, Coquille, and Rogue Rivers remained above flood stage for about 5 days although flood stages on tributaries and other streams were for lesser duration. In general, the December 1964 flood on the Oregon coastal streams was approximately a 50-year flood, but the probable recurrence frequency is different for each stream.



Brown's Bridge which crossed the N. Umpqua River December 1964; (a) just previous to collapse and, (b) the following morning. (USCE)

Records of flooding in the southern Washington part of Sub-region 10 are fairly complete back to 1930, but little is known about floods or flood damages on the streams from the Quinalt north. Floods have been more localized on the Washington streams than in Oregon, and no single flood has caused the maximum flood of record on more than two or three streams. The floods of December 1933 were the most widespread in southwestern Washington. At that time, North River near Raymond reached its highest recorded stage, and the second or third highest stages were recorded on the Willapa (tidal), Chehalis, and Satsop Rivers.

Table 100 lists the available data from the more significant floods on the coastal streams.

Table 100 - Summary of Major Floods and Damages
in Subregion 10

<u>Stream</u> (gage)	<u>Discharge</u> (cfs)	<u>Date of</u> <u>Flood</u>	<u>Damages at</u> <u>Time of</u> <u>Flood</u>	<u>Damages at 1967</u> <u>Price Level</u>
Rogue R. (Grants Pass)	152,000	Dec 64	\$16,382,000	\$19,331,000
	135,000	Dec 55	4,048,530	6,275,000
	77,000	Jan 53	<u>1/</u>	<u>1/</u>
Coquille R. (Coquille)	110,000	Dec 64	3,073,000	3,626,000
	95,000	Dec 45	<u>1/</u>	<u>1/</u>
	110,000	Dec 55	2,596,830	4,025,000
Coos R. (nr Allegany)	13,600	Dec 54	<u>1/</u>	<u>1/</u>
	8,100	Nov 60	<u>1/</u>	<u>1/</u>
	7,990	Dec 55	127,220	197,000
	5,560	Dec 64	1,191,000	1,405,000
Umpqua R. (nr Elkton)	265,000	Dec 64	25,964,000	30,638,000
	218,000	Dec 55	2,143,140	3,322,000
	208,000	Oct 50	<u>1/</u>	<u>1/</u>
Alsea R. (nr Tidewater)	41,800	Dec 64	492,000	581,000
	32,800	Nov 60	<u>1/</u>	<u>1/</u>
	32,200	Dec 55	<u>1/</u>	<u>1/</u>
Siletz R. (Siletz)	40,800	Nov 21	<u>1/</u>	<u>1/</u>
	32,200	Jan 65	<u>1/</u>	<u>1/</u>
	30,500	Dec 64	391,000	461,000
Trask R. (nr Tillamook)	23,000	Dec 64	483,000	570,000
	20,200	Dec 55	40,230	62,000
	20,000	Dec 33	<u>1/</u>	<u>1/</u>
Wilson R. (nr Tillamook)	32,100	Dec 64	818,000	965,000
	30,000	Dec 33	<u>1/</u>	<u>1/</u>
	21,100	Dec 55	43,020	67,000
Nehalem R. (nr Foss)	43,400	Jan 64	<u>1/</u>	<u>1/</u>
	40,400	Dec 64	328,000	387,000
	39,300	Dec 55	25,710	40,000
Naselle (Naselle)	11,400	Jan 35	<u>1/</u>	<u>1/</u>
	10,300	Feb 49	<u>1/</u>	<u>1/</u>
Willapa (Lebam)	4,930	Feb 49	<u>1/</u>	<u>1/</u>
	4,630	Dec 66	<u>1/</u>	40,000
Willapa (tidal)(Raymond)	16.5	Oct 34	<u>1/</u>	143,000
	16.4	Dec 33	<u>1/</u>	135,000
	15.8	Dec 67	<u>1/</u>	<u>1/</u>

Table 100 (Cont'd)

Stream (gage)	Discharge (cfs)	Date of Flood	Damages at Time of Flood	Damages at 1967 Price Level
North (R.M. 7)	35,000	Dec 33	1/	1/
Chehalis (Grand Mound)	48,400	Dec 37	1/	\$3,500,000
	45,700	Dec 33	1/	2,885,000
	38,000	Jan 35	1/	1,380,000
	38,000	Feb 51	1/	1,380,000
	37,400	Jan 54	1/	1/
	35,700	Jan 64	1/	863,000
	34,400	Dec 66	1/	1/
Chehalis (tidal)(Aberdeen)	14.8	Dec 33	1/	1,525,000
	13.7	Jan 64	1/	1/
Newaukum (Chehalis)		Jan 64	1/	1/
Skookumchuck (R.M. 22)	6,710	Dec 53	1/	58,000
	6,230	Dec 55	1/	1/
	5,990	Jan 64	1/	1/
	5,770	Feb 49	1/	1/
Satsop (Satsop)	46,600	Dec 35	1/	267,000
	36,200	Feb 51	1/	140,000
	32,800	Nov 62	1/	118,000
	32,000	Dec 56	1/	1/
Wynoochee (Below Black Cr)	33,000	Nov 55	1/	130,000
	28,000	Feb 51	1/	96,000
	27,600	Nov 49	1/	92,000
	26,400	Dec 56	1/	86,000
	24,500	Jan 61	1/	74,000
Humptulips (Humptulips)	33,000	Jan 35	1/	1/
Quinault (Quinault Lake)	52,600	Nov 09	1/	1/
	50,200	Nov 55	1/	1/
	43,300	Jan 61	1/	1/
Oueets (Clearwater)	130,400	Jan 35	1/	1/
	118,400	Nov 55	1/	1/
	108,400	Dec 56	1/	1/
	90,800	Jan 61	1/	1/
	85,600	Nov 63	1/	1/
Hoh (U.S. Hwy. 101)	46,000	Jan 61	1/	1/
	38,700	Nov 49	1/	1/
	38,700	Nov 62	1/	1/
Quillayute (Fairholm on Soleduck)	23,500	Nov 49	1/	1/
	19,800	Dec 33	1/	1/
	18,800	Nov 34	1/	1/
	18,000	Nov 55	1/	1/

1/ Not available.

PRESENT STATUS

Existing Measures

Flood Control Storage

Existing reservoirs and those authorized and under construction are shown on figure 26.

Emigrant Reservoir, part of an irrigation project on Bear Creek, a tributary of Rogue River, partially controls floods on Bear Creek through Medford with joint-use storage. A maximum of 30,000 acre-feet of storage for flood control is assured from October through December, but the effectiveness of the storage is limited by the size of the drainage area controlled, about 21 percent of the area above Medford. The project does not have any noticeable effect on the Rogue River.

Wynoochee Reservoir, under construction on the Wynoochee River in the Chehalis River Basin, will provide 35,000 acre-feet of storage for flood control.

Farm ponds and small reservoirs, numbering 2,030, have a total capacity of 8,600 acre-feet.

Local Protection Projects

Local protection projects in Subregion 10 are summarized in table 101. Most of these projects are levees which provide minimal protection. Levees along the streams above tidewater are generally without setback from the channels, and few are adequately revetted. Damages by major floods to these projects usually include destruction of critical sections of levees. The Federal government has constructed a few revetments to protect highways, irrigation canals, sanitary facilities, and similar public works.

Table 101 - Existing Local Protection Projects,
Subregion 10

Stream 1/ or Estuary 2/	Length of Protective Works in Miles 3/			Acres 3/ Protected
	Levee	Revetment	Channel Improvement	
Rogue River	2.6	0.9	None	1,192
Coquille (tidal)	1.1	0.8	None	4,622
Coos Bay estuary	1.8	1.1	2.5	2,851
Umpqua estuary	14.6	0.9	None	1,643
Umpqua River	None	0.2	4.0	250
Siuslaw (tidal)	2.8	None	None	334
Yaquina (tidal)	0.5	0.1	None	1,055
Nestucca estuary	5.4	1.6	None	1,113
Tillamook Bay estuary	15.2	1.1	0.8	2,074
Nehalem (tidal)	3.3	None	None	1,624
Necanicum (tidal)	None	0.2	None	Not avail.
Willapa Bay estuary	13.6	None	None	2,730
Grays Harbor estuary	19.6	None	None	Not avail.
Chehalis River	6.15	None	0.6	Not avail.
Humtulsips River	0.8	None	None	Not avail.
Various locations on tributaries	114.3	121.8	246.1	Not avail.

1/ Includes tributaries.

2/ Includes tidal reaches of streams.

3/ Not complete.

Flood Plain Regulation Program

Interim flood plain information reports showing the extent of flooding by Rogue and Umpqua Rivers and tributaries during December 1964 have been published. Final flood plain information studies were published in 1968 for the Chehalis and Skookumchuck Rivers at Centralia-Chehalis and for the Skookumchuck River at Bucoda. These show the extent of flooding by an intermediate regional flood (about 100-year frequency) and by a standard project flood. A report similar to the above final information reports is being prepared by the Geological Survey in cooperation with the Oregon State Water Resources Board and Douglas County for Elk Creek (Umpqua River) in the vicinity of Drain.

Watershed Protection

In the heavy rainfall belt west of the Coast Range, watershed protection is not as critical as in the drier areas farther inland. The predominant use of croplands in this area is for pasture and native hay, and the lands are thus sodded during the wet season. Most other erodible croplands carry cover crops through the winter. Range and forest lands usually have sufficient ground cover to prevent erosion except by fairly large streams or where cut up by roads. Even clear cut forests develop ground

cover within a few years. The interior subbasins of the Rogue and Umpqua, however, have significant watershed problems. In the interior areas, 62 percent of the cropland vulnerable to flooding or sheet erosion, 22 percent of rangeland, and 21 percent of disturbed forest lands receive regular land treatment measures to prevent erosion and to retard runoff. It is estimated that the soils of Subregion 10 have a water holding capacity of 8,185,000 acre-feet or an average of 6.52 inches over the entire area.

Flood Forecasting

Flood warnings are issued by the National Weather Service for 15 key stations on the larger streams. As Subregion 10 extends along the coastal areas of two states, 3 River District Offices - Medford, Portland, and Seattle - are involved. Table 102 shows the key river locations, the flood stage and corresponding discharge, and the River District responsible for the flood warning program.

Flood warnings are first issued when forecasts indicate that near bankfull stages, 1 to 3 feet below actual flood stages are expected. When flood stage is reached, forecasts are issued at 12-hour intervals or more frequently if weather conditions change radically. Forecasts are continued until streams recede to below bankfull stages and all danger is passed.

Close cooperation is maintained with State, County, and City authorities; Federal agencies; Civil Defense officials, private and public utilities; and the news media (radio, television, and newspapers).

Beginning in 1968, a storm tide warning service was established for coastal areas of Oregon and Washington. The Portland Weather Forecast Office issues warnings for Oregon and the Seattle office for Washington. Storm tide warnings indicate that tidal flooding is expected along low-lying coastal areas. Warnings include expected tidal stages above mean lower low water or departure from normal high tide, degree of flooding, possible wave or surf battering, and significant beach erosion.

The U. S. Coast and Geodetic Survey prepares warnings and advisories of tsunamis, or sea waves generated by earthquakes, for coast areas. Dissemination to the local population is the responsibility of State and local Civil Defense organizations. Agencies such as the Weather Bureau, Coast Guard, police, et al, cooperate in the dissemination of warnings.

Table 102 - Flood Stages and Flood Warning Stations, Subregion 10

Location	Stream	Flood Stage (feet)	Discharge (cfs)	National Weather Service River District Office	
Dodge Bridge, Oregon	Rogue R.	10	31,800	Medford, Ore.	
Raygold, Oregon	Rogue R.	12	36,900	"	"
Grants Pass, Oregon	Rogue R.	19	56,800	"	"
Gold Beach, Oregon	Rogue R.	1/	-	"	"
Kerby, Oregon	Illinois R.	1/	-	"	"
Applegate, Oregon	Applegate R.	13	16,500	"	"
Myrtle Point, Oregon	Coquille R.	35	18,500	"	"
Coquille, Oregon	Coquille R.	21	Tidal Estuary	"	"
Winston, Oregon	S. Umpqua R.	26	65,400	"	"
Roseburg, Oregon	S. Umpqua R.	22	61,300	"	"
Winchester, Oregon	N. Umpqua R.	18	75,500	"	"
Elkton, Oregon	Umpqua R.	33	130,700	"	"
(tentative)					
Tidewater, Oregon	Alsea R.	1/	-	Portland, Ore.	
Beaver, Oregon	Nestucca R.	1/	-	"	"
Siletz, Oregon	Siletz R.	1/	-	"	"
Foss, Oregon	Nehalem R.	1/	-	"	"
Centralia, Washington	Chehalis R.	19	21,000	Seattle, Wash.	
Centralia, Washington	Skookumchuck R.	85	-	"	"
Satsop, Washington	Satsop R.	35	34,500	"	"
Montesano, Washington	Wynoochee R.	19	21,100	"	"

1/ Flood stage not determined.

Dissemination methods include radio and television announcements, sirens, loudspeaker trucks and aircraft, and door-to-door patrols by Civil Defense officials and policemen.

Accomplishments

Storage

Emigrant Reservoir reduced the stage of the 1964 flood on Bear Creek by 1.2 feet at Medford and prevented an estimated \$70,000 in damages. It is considered to protect about 1,000 acres from flooding and to prevent damages of \$55,000 annually (1968 prices and development).

The 35,000 acre-feet of flood control storage in Wynoochee Reservoir will control a flood of about 27,000 cfs on Wynoochee River. It will protect about 4,040 acres from floods up to a 10-year frequency and reduce average annual damages by \$24,000.

Local Protection Projects

Levees protect urban and built-up areas at Reedsport and Centralia from floods of 200-year frequency. The levee protecting the city-county airport at Chehalis would provide a high degree of protection, but floods in excess of about 8-year frequency flow around one end of the levee. Inflow from moderate floods can be prevented by sandbagging and emergency levee construction and some inflow can be pumped back to the river without causing damages. The levees in the Aberdeen-Hoquiam area have not been overtopped since 1934, but do not have an active coordinated maintenance program, and their effectiveness against a 15-foot tide such as occurred in 1933 is uncertain. The degree of protection for rural lands ranges from 2- to 200-year. In most of the protected areas, residents accommodate to the more frequent floods and cropping practices limit damages. Problem areas are discussed under remaining flood problems. The revetments protect specific facilities such as highway bridge approaches, sewage treatment plants, etc., rather than area per se. Stream channel improvements protect against floods of 1 and 2-year frequency, but also reduce damages during larger floods and promote faster runoff following inundation.



Chehalis River at Chehalis Airport, December 1966. (USCE)

Average annual damages prevented by Corps of Engineers local protection projects in Oregon are \$660,000 at 1968 prices and development. Such information was not available for Washington.

Watershed Protection

Two comprehensive watershed projects protect 3,000 acres of agriculture land from flooding. Average annual damages on these lands are reduced by \$47,000.

Remaining Flood Problems

Remaining damages are summarized in table 103. These damages result from inundation, streambank erosion, deposition of silt and debris, and beach and estuarine erosion.

Inundation

Serious inundation from streamflow occurs inland in the Rogue, Coquille, Umpqua, and Chehalis River Basins and from storm and tidal action around many estuaries and along tidal streams.

In the Rogue River Basin damages occur to small individual areas scattered along a 75-mile reach of the main river downstream from the Lost Creek Damsite and to similar areas along the tributaries, notably Big Butte Creek, Bear Creek, Evans Creek, Applegate River, and Illinois River. Most of the damages are to agricultural lands, but urban areas in and around Medford and Grants Pass and portions of the towns of Shady Cove and Rogue River are flooded. Several highway bridges have been washed out by recent floods, and extensive motel and other recreational developments along the reaches above Shady Cove to the Lost Creek Damsite and for about 10 miles above Grants Pass are subject to flooding. Damages occur in widely scattered areas along the reach through the Coast Range and in the harbor area at the mouth. The segment of the Rogue River extending from the mouth of the Applegate River (mile 95) downstream to the Lobster Creek Bridge (mile 11) with the land adjacent thereto, is a component of the national wild and scenic rivers system.(3)

The principal damages in the Coquille River Basin occur during the late spring floods which destroy newly established crops and disrupt production from dairy cattle, although lands along the lower river are flooded nearly every other winter and severely flooded during major regional floods.

In the Umpqua River Basin, damaging floods are almost an annual occurrence. Most of the damages are on agricultural lands in the central valley portion of the basin upstream from the confluence with Calapooya Creek and along the lower reaches of Elk,

Calapooya, Sutherlin, Deer, Lookingglass, Myrtle, and Cow Creeks. Urban and urban type areas adjacent to Roseburg, Winston, and Myrtle Creek and portions of Drain, Sutherlin, and Canyonville are inundated. Major floods damage buildings, equipment and supplies, highways and bridges, railroads, and parks and recreation areas. Agricultural and residential damages occur to isolated ranches and summer homes along the reach through the Coast Range between Elkton and Reedsport.

In the Chehalis River Basin, nearly all of the agricultural damages occur upstream from the confluence with the Satsop River, and most of the urban damages result from tidal flooding in the Aberdeen-Hoquiam area. Approximately 20,000 acres of farmland along the main river between the Newaukum and Satsop, 1,000 acres on Skookumchuck, and additional lands along the Satsop and Newaukum are subject to flooding. Some flooding occurs nearly every year, but most of the lands so flooded are used for hay or pasture and little damages result. Some farm buildings are flooded by 5-year floods, and major floods occur at about 20-year frequency. Average annual damages (agricultural) in these areas amount to \$573,000, and an additional \$12,000 damages occur in the Wynoochee and Wishkah basins. Urban and transportation damages amount to \$275,000 annually in the Chehalis area. Although there



Chehalis River at Chehalis, December 1966. (USCE)

has not been serious flooding in the Aberdeen-Hoquiam area due to tidal action in recent years, it is estimated that a recurrence of a 15-foot tide such as occurred in 1933 and 1934 would cause more than \$1.5 million damages. Average annual damages are estimated to be \$310,000.

Approximately 10,000 acres of farmland along the lower reaches of the tributaries to Tillamook Bay are flooded when heavy runoff coincides with exceptionally high tides. Average annual damages amount to \$223,000 and the threat of flooding prevents the land from being used for more valuable crops.

In upland areas, over 222,000 acres of cropland, 41,000 acres of forest land, and 17,000 acres of range and pastureland are subject to flooding. Average annual damages in these areas amount to \$1,760,000 in Oregon and \$1,522,000 in Washington.

Riverbank Erosion

Riverbank erosion occurs along most of the streams in the subregion during floods and normal high water. It is estimated that 142 miles of streambanks in Oregon and 250 miles in Washington are eroding. In most areas, the erosion problems are widely scattered at sharp bends, but the Applegate River and several minor



Erosion in the Coquille Valley. (USCE)

tributaries of Rogue River have several miles of almost continuously eroding banks. Values of land subject to destruction range from \$100 to \$300 per acre for croplands to more than \$3,000 per acre for desirable recreation frontage. Erosion also damages or threatens destruction of utilities, irrigation canals and headworks, and transportation and communication facilities. It is estimated that 240 miles of streambank are subject to serious erosion, which, at an estimated average annual lateral retreat of 1.0 foot, causes an average annual land loss of 290 acres.

The economic value of riverbank erosion losses is estimated to be \$1,042,000, including \$520,000 due to loss of land, \$442,000 due to sedimentation, and \$80,000 due to miscellaneous factors. Approximately 80 percent are rural.

Beach and Estuarine Erosion and Accretion

Serious erosion problems due to wave and tidal action occur along more than 12 miles of levees around reclaimed tidal flats. Minor erosion occurs in other areas, but these problems can be controlled by normal maintenance programs. Known beach erosion problems include the following:

Newport, Oregon - The bluff along the ocean front at Newport is between 40 and 60 feet high and is composed of a sandstone and shale formation. During the last 50 years, it has receded approximately 250 feet. At this time, the top of the bluff is occupied by several motels and beach homes which will be lost if the erosion continues.

Tillamook Bay, Oregon - The spit on the south side of the entrance to Tillamook Bay extends approximately 4 miles to a firm headland at Cape Mears. It is nearly 2,500 feet wide at its widest point, but consists of a narrow neck about 750 feet wide near the southern end. The spit consists mostly of unconsolidated dune sand and has eroded and accreted during historical times. A million dollar resort was constructed on the spit in 1906 and 1907 and destroyed by beach erosion between 1935 and 1939. The neck was breached in 1952, and the breach threatened to become a second entrance to the bay. On the premise that the second entrance would seriously disrupt existing navigation routes on Tillamook Bay, the Corps of Engineers closed the breach in 1956. However, the spit continues to erode, and the problem has not been permanently solved.

Seaside, Oregon - Beach sands accrete in front of the city of Seaside. Annual maintenance is required to remove wind-blown sands which cover beach-front streets and properties to depths

of several feet. The shifting mouth of the Necanicum River occasionally threatens to destroy the city's sewage disposal plant.

South Jetty, Mouth of Columbia River - The beach is eroding on the ocean side of the south jetty located at the mouth of Columbia River, and depths are increasing offshore. The Corps of Engineers has constructed fences to trap drifting sands, but the fences are subject to storm wave damage, and little permanent results have been achieved. No serious immediate problem exists, and the Corps is keeping the area under surveillance to make whatever corrective measures are necessary to protect the south jetty.

Willapa Bay, Washington - Erosion is seriously damaging about 3 miles of beach at Cape Shoalwater on the north side of the entrance to Willapa Bay. The beach erosion is accompanied by a northerly shift of the deep-water entrance to the bay and accretion on the end of the Long Beach peninsula on the south side of the bay entrance. The entire entrance has shifted northerly more than 2 miles since 1890, when the first surveys of the area were made. In 1968, the rate of erosion was about 150 feet per year; continued erosion at that rate would cut a section of State Highway 105 during the winter of 1971-72 after which 600 acres of cranberry bog would be exposed to salt water flooding during extreme high tides. The erosion is expected to continue northerly at its present rate until about 1990 or 2000 by which time it will have reached a more resistant formation about half mile north of the present beach line. Corrective measures have been attempted, but the works were destroyed when undercut by the deep-water erosion.

Beach erosion occurs at several other locations but has not been a problem because no developments were endangered. It is estimated that beach erosion control measures may be needed on as much as 40 miles of coastline prior to 2020.

PROJECTIONS AND NEEDS

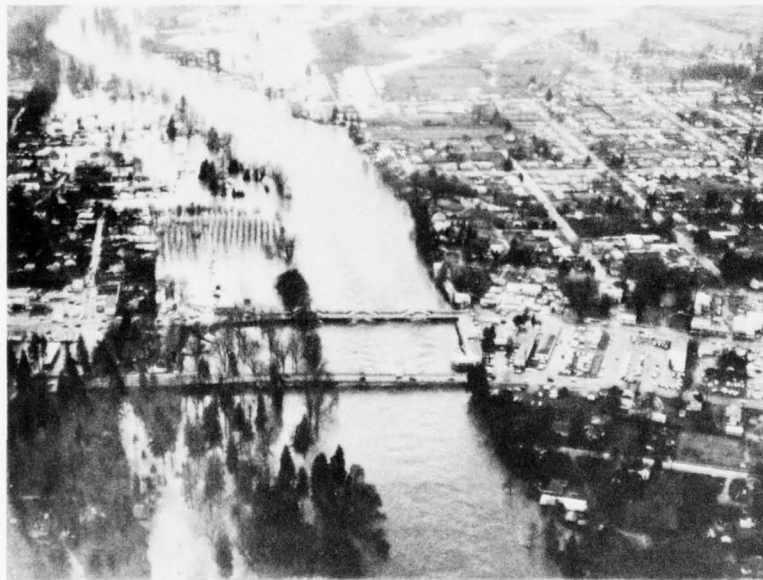
Economic Trends

The population of the economic subregion, which does not include the interior Chehalis Basin, was 405,500 in 1965 and is projected to be 465,500 in 1980, 575,400 in 2000, and 708,900 in 2020. This represents a growth of nearly 1.1 percent per year with a slightly faster growth during the early part of the forecast period. Parts of the subregion not included in the economic subregion are expected to grow at comparable rates. As in other

parts of the region, agricultural employment is expected to decline, rural population to remain at its present level or decline slightly, and most population growth to occur in or adjacent to urban centers. Employment opportunities to support the population growth will result from "amenity resources" (climate, coastal, and recreational opportunities); increased development and use of port facilities; further development of natural resources, primarily timber, and diversification of industry. Significant increases in manufacturing production are expected in the pulp and paper industry, plywood manufacturing, and food processing. Trades and services are expected to show a steady growth to match needs of the resident population and of recreationists from outside the area.

Land-Use Trends in the Flood Plain

In most areas, use of the flood plain will continue about as at present. There will be some increases in hay and pasture production through irrigation, use of fertilizers, and other cropping practices, and some lands will be converted to other crops. However, the changes to other crops will generally occur on the less frequently flooded portions of the flood plain, and damages on agricultural lands will not increase dramatically. Urban expansion onto flood plain areas adjacent to several of the larger cities will occur unless prevented by zoning regulations. This will be especially true at Grants Pass where partial protection afforded by Lost Creek and Elk Creek Dams will give a false



*Rogue River at Grants Pass, Oregon, looking downstream, December 1964.
(USCE)*

sense of security. Coquille has a singular problem in that there is no room for expansion except in the flood plain and there is a tendency to build behind inadequate levees or on fills overtopped by major floods. Industrial growth is expected to include establishment of heavy industry in the Astoria, Coos Bay, and Grays Harbor areas, expansion of existing timber-based industries and food processing, and expansion of non-resource based manufacturing adjacent to Interstate 5 in the Rogue, Umpqua and Chehalis Basins.

A new flood problem is developing along several of the smaller streams. Recreation homes, fishing cabins, motels, and similar structures are being built on the streambanks. There are no building regulations in many of these areas, and new owners are not aware of the flooding potential. Motels and restaurants are often deliberately placed in flood hazardous areas to take advantage of scenery and other esthetic qualities. Streams where this type of development is expected include the Alsea, Siletz, Nestucca, and Nehalem Rivers in Oregon and the Copalis and Moclips Rivers, a few miles north of Grays Harbor in Washington. Similar development is occurring along the ocean front.

Future Flood Damages

Average annual damages in the major flood problem areas are given in table 103 for present and future development. Present damages are divided into two categories, urban and rural. Urban damages include industrial, commercial, urban residential, transportation, and some rural residential of urban or suburban nature. Rural damages are generally limited to agricultural development and farm buildings. Urban damages are projected at growth rates selected for each area on the basis of recent and

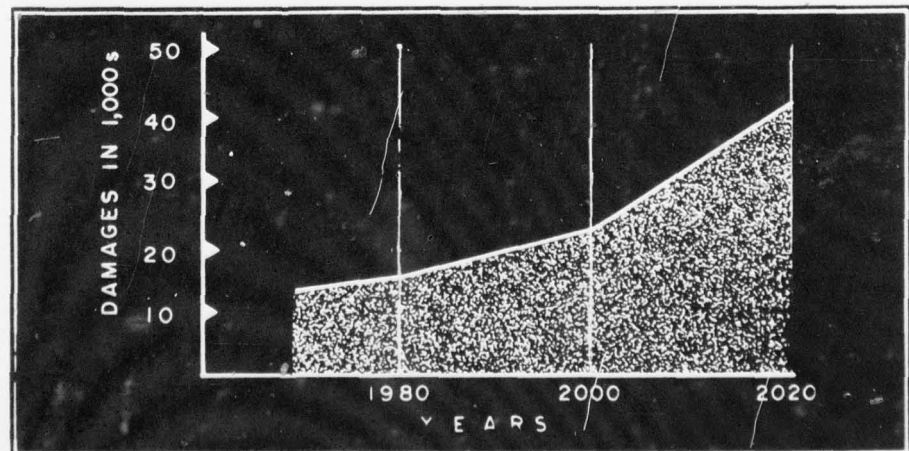


Figure 27. Projected Average Annual Flood Damages, Subregion 10.

anticipated development. The maximum projected growth is at the rate of increase in total personal income for urban residents, but lower rates are used for most areas. Rural damages are projected at the expected rate of growth of production of the typical crops grown in flood plain areas.

Streambank Erosion

The annual loss of land due to streambank erosion is not expected to change except as influenced by corrective measures. The value of land loss and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being primarily based on removal costs, will remain constant. Future average annual damages from this source are estimated to amount to \$1,182,000 in 1980, \$1,627,000 in 2000, and \$1,982,000 in 2020.

Summary of Future Flood Damages

The present-day average annual damages of \$11.3 million are 56 percent rural and 44 percent urban.

Agricultural damages will increase a total of approximately 180 percent by the year 2020 due to increases in agricultural

Table 103 - Average Annual Damages, Subregion 10

Stream Basin	Damages in \$1,000, 1967 Price Levels					
	1967 Development		Total	1980	2000	2020
	Rural	Urban				
Chetco	80	30	110	141	215	331
Rogue	790	1,200	1,990	2,920	5,700	11,400
Coquille	374	124	498	642	977	1,496
Coos	146	49	195	250	384	582
Umpqua	497	1,707	2,204	3,100	5,500	9,900
Siuslaw	158	53	211	270	412	631
Alsea	61	20	81	104	158	242
Yaquina	31	10	41	53	81	125
Siletz	3	-	3	4	6	10
Nestucca	17	18	35	46	74	119
Trask	104	-	104	133	206	287
Wilson	89	30	119	155	238	370
Nehalem	47	2	49	63	95	144
Other	62	40	102	132	201	315
Tributary Areas	1,430	330	1,760	2,323	3,450	5,122
Total Oregon	3,889	3,613	7,502	10,336	17,697	31,074
Willapa	7	26	33	44	107	222
Chehalis	585	585	1,170	1,731	3,021	5,689
Tributary Areas	1,012	510	1,522	1,842	2,039	2,222
Total Washington	1,604	1,121	2,725	3,617	5,167	8,133
Riverbank erosion, both states	834	208	1,042	1,182	1,627	1,982
Total Subregion	6,327	4,942	11,269	15,135	24,491	41,189

investment and increases in output. The increase in damages will also be caused in part by more intensified land use, by change-over to field crops, and by use of more advanced farm equipment, which will be exposed to flood damages.

Urban damages will increase approximately 455 percent by the year 2020 as a result of improvement of existing industrial and transportation development, the addition of new industrial sites, and the general development of the area.

MEASURES REQUIRED TO SATISFY NEEDS

Storage

Very little potential exists for developing flood control storage in Subregion 10. Most streams form in steep narrow valleys and do not have suitable reservoir sites above the area for which protection is desired. Further, the characteristics of the seasonal rain limits the potential for making joint use of storage space. Damaging floods may occur as late as the last of April or there may not be sufficient rainfall after the middle of February to assure reservoir filling for conservation purposes.

Rogue River Basin

More than 1.25 million acre-feet of storage would be needed to control flooding on the Rogue River and its principal tributaries in the areas where problems exist. This would not include the canyon section below the mouth of the Applegate which has been designated as a part of the wild and scenic rivers system. Lost Creek and Elk Creek Reservoirs will provide a total of 225,000 acre-feet of storage for flood control and the Applegate project will provide 55,000 acre-feet. This storage will substantially reduce the extent of flooding on the Rogue and Applegate Rivers but will not completely control major floods. Storage on some other tributaries has been considered as part of irrigation studies.

Coquille Basin

Four principal tributaries of the Coquille River converge in the vicinity of Myrtle Point. Any one of the four may have a flow equal to the bankfull capacity of the river below Myrtle Point on an average of once every 3 years. Control of major floods would require more than 500,000 acre-feet of storage and could not be achieved without control of all four tributaries. Of

the two sites listed in table 104, a reservoir at the Fairview site would control the North Fork but the Camas Valley site is too far upstream to control the Middle Fork. Other sites exist on the North Fork below the confluence with the East Fork and on the South Fork, but projects at these sites would block important fish runs and require extensive highway, railway, utility, and other relocations in difficult terrain. Full control of the Middle Fork could not be realized.

Umpqua Basin

A reasonable degree of flood protection on the Umpqua and South Umpqua Rivers could be achieved with about 300,000 acre-feet of upstream storage. This amount apparently could be provided at either the Days Creek or Tiller Reservoir sites on the South Umpqua River. Additional flood reduction could be provided by 30,000 acre-feet of storage on Cow Creek and 26,000 acre-feet on Calapooya Creek. These amounts of storage would be effective in the principal problem areas but would not prevent flooding of isolated farm tracts along the river below the confluence of Calapooya Creek nor materially reduce stages at Reedsport. Detailed studies are underway for multiple-purpose storage development on the South Umpqua River. After completion of the authorized projects in the Rogue Basin, the most critical need for flood control storage in the Oregon portion of Subregion 10 will be in the Umpqua Basin.

Other Oregon Streams

Flooding in some of the areas around Tillamook could be reduced by about 300,000 acre-feet of upstream storage which is potentially available at sites on the Wilson and Trask Rivers. However, the flood control effects of upstream storage would be limited in view of the effects of tidal action, which influences depths of inundation in the flood plain.

Approximately 115,000 acre-feet of flood-control storage on the Nestucca River would considerably reduce flooding in the middle reach of the stream but would not eliminate damages in the Pacific City-Woods area. That area is located near the mouth of the stream and receives damages from tidal action, as well as from upstream flood runoff.

On the Nehalem River, 350,000 acre-feet of storage would reduce flooding to damages from tidal action in the downstream reach. The upstream storage is potentially available at the Elsie site, but construction of a reservoir would entail high

relocation costs and would inundate a large percentage of the basin's agricultural land.

Flood damages in the Yaquina River Basin occur primarily in tidal areas and would not respond appreciably to control by upstream storage.

Chehalis Basin

Control of the Chehalis River to zero damaging flows, 17,000 cfs at Grand Mound, is not practicable because of inflow from below all suitable damsites. Control of a 100-year flood to 25,000 cfs at Grand Mound would require 132,000 acre-feet. To be effective, such storage would have to comprise 108,000 acre-feet on the Chehalis, effective at the forks, and 24,000 acre-feet effective on both forks on the Newaukum. Flood control storage on the Skookumchuck River was found not economically justified in 1968, prior to construction of the coal-fired power plant and associated water supply near Centralia, and would now be more expensive because of that construction.

Several suitable storage sites are shown on figure 26 and listed in table 104. A dam at the Ruth site would provide the needed capacity on the Chehalis River but would be expensive because of high real estate and relocation costs. Some control could be achieved with dams at the Pe Ell, Doty, Boistfort or Point Hill sites. The Onalaska site on the South Fork Newaukum also would be expensive because of high real estate and relocation costs; the other sites on the Newaukum would not pose particular problems.

Other Washington Streams

Storage needs on the Wynoochee River are being met by the project under construction to the extent presently justifiable. Needs on other streams have not been determined. The level of flood damages and the lack of other needs for storage preclude the possibility of justifying storage projects.

Table 104 - Potential Storage Sites, Subregion 10 ^{1/}

<u>Basin & Stream</u>	<u>Site</u>	<u>Potential Storage (ac.-ft.)</u>	<u>Approximate Cost per Acre-Foot for Usable Storage (Dollars)</u>
<u>Rogue River Basin</u>			
Rogue River	Lost Creek ^{2/}	315,000	
Elk Creek	Elk Creek ^{3/}	95,000	
Applegate River	Applegate ^{3/}	75,000	
<u>Coquille River Basin</u>			
N. Fk. Coquille River	Fairview	71,000	234
M. Fk. Coquille River	Camas Valley	29,000	287
<u>Coos River Basin</u>			
S. Fk. Coos River	Fall Creek	330,000	
<u>Umpqua River Basin</u>			
S. Umpqua River	Days Creek	600,000	100
	Tiller (alternative to Tiller)	510,000	165
Cow Creek	Galesville	70,000	381
Calapooia Creek	Hinkle	42,500-70,000	292-222
<u>Yaquina River Basin</u>			
	Depot Creek	3,000	400
	Beaver Creek	3,000	470
	Lower Elk Creek	83,000	150
	Upper Elk Creek	42,000	200
<u>Nestucca River Basin</u>			
	Blaine	130,000	220
<u>Tillamook Bay Streams Basin</u>			
Wilson River	Cedar Creek	200,000	172
Trask	Hollywood	85,000	226
	Ginger Peak	185,000	119
<u>Nehalem River Basin</u>			
	Clear Creek	75,000	207
	Elsie	450,000	124
<u>Chehalis River Basin</u>			
Chehalis River	Pe Ell	85,000	-
Chehalis River	Dryad	24,000	-
Chehalis River	Meskill	110,000	-
Chehalis River	Ruth	130,000	430
Elk Creek	Doty	140,000	166
Chehalis	Boistfort	180,000	-
	Point Hill	-	-
<u>Newaukum</u>			
	Alpha	125,000	440
	Onalaska	120,000	-
	Bear Creek	23,000	-
	Logan Hill	95,000	-
	Middle Fork	100,000	-

^{1/} This information is furnished for possible use in plan formulation and includes the total storage capability at many sites. The amount that will be usable for flood control would in many cases be considerably less.

^{2/} Under construction.

^{3/} Authorized.

Levees and Floodwalls

An estimate of future levee needs in Subregion 10 is shown in table 105. The estimate is based on studies from 1950 to date and includes projects for which Federal participation had been authorized but allowed to expire because rights of way could not be furnished locally. Generally, the proposed work would be an improvement or extension of existing levees. Floodwalls are considered where space is limited. Cost estimates were made at the time of the study, but have been updated to 1969 dollar value. The estimates have not been reassessed to include current development along the rights of way. In work of this nature, annual operation and maintenance costs generally run about one-half percent of initial construction costs.

Table 105 - Levee and Flood Wall Needs, Subregion 10

Stream Basin	Length of Levees	Cost in \$1,000 (1969)
	Needed Miles	
Oregon		
Rogue	5	1/
Coquille	2.5	487
Umpqua	24	12,860
Nestucca	30.5	6,483
Tillamook Bay	47	8,097
Nehalem	10	2,545
Elk Cr. (Cannon Beach)	0.5	65
Total Oregon	119.5	30,537
Washington		
Willapa Bay	2	1,000
Chehalis River	68	22,275
Total Washington	70	23,275
Total Subregion	187	53,812

1/ Not available.

Land Measures and Minor Tributary Structures

Cropland practices still needed include 305,000 acres of conservation cropping systems, 101,000 acres of crop residue use, and 7,300 miles of drainage conduits and ditches. Needed measures on forest lands include 125,600 acres of erosion control treatment and 6,500 miles of road and trail restoration. Rangeland practices include 66,000 acres of grass seeding, 37,000 acres of brush control, and better grazing control on 82,000 acres. Needed structural measures in small watersheds include 3,600 ponds and small reservoirs with a total capacity of 9,600 acre-feet, 1,300 miles of levees, 5,000 miles of stream channel improvement, 50 miles of stream channel stabilization, 1,600 miles of streambank protection, and 625 miscellaneous other

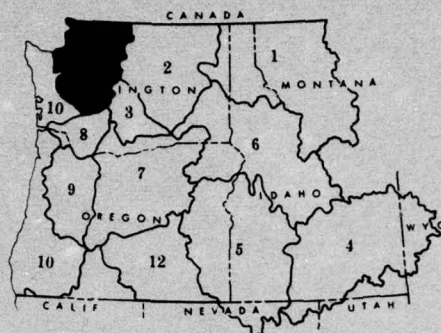
structures. Additional details on these aspects are included in Appendix VIII - Land Measures and Watershed Protection.

Comprehensive Watershed Program

Comprehensive treatment comprising land measures and flood control structures on minor tributaries will be needed on 91 watersheds prior to 2020. Within these watersheds, 124,400 acres are subject to flooding. The measures included on these watersheds are included in the above subregion totals.

Zoning

Most flood prone areas of Subregion 10 are not expected to have exceptional growth that would indicate an urgent need for flood plain zoning regulations. Nearly all of these areas, however, receive inadequate, if any, protection, and as a minimum, zoning ordinances should spell out the hazards and degree of risk. There are some notable exceptions to this pattern. The Rogue River from Lost Creek Dam to the confluence of Little Butte Creek should be adequately controlled and needs no zoning. However, in the vicinity of Grants Pass an urgent need for zoning exists as there is considerable development in the flood plain and more will be drawn into the area as partial protection by Lost Creek and Elk Creek Dams will lend a false sense of security. In the vicinity of Coquille, flood proofing requirements that the main floors of new buildings be above a certain elevation would retard the growth of future flood damages. Similar regulations are indicated for the area around Tillamook. Appropriate flood plain zoning regulations are urgently needed in the Chehalis-Centralia area.



LOCATION MAP

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11

SUBREGION 11

PUGET SOUND

GENERAL

Location and Extent

Subregion 11, encompassing 13,355 square miles in western Washington, comprises Puget Sound, Hood Canal, the United States portion of the Strait of Georgia, the eastern portion of the Strait of Juan de Fuca, and all areas in the United States tributary thereto. It is bounded on the north by Canada, on the east by several central Washington basins in Subregions 2 and 3 across the Cascade Range, on the south by the Cowlitz River Basin in Subregion 8, and on the southwest and west by the coastal basins in Subregion 10. The subregion is approximately 100 miles wide from east to west over most of its 170-mile length. The Kitsap Peninsula and the large islands in the subregion do not have major streams or problems normally associated with stream flooding. These areas are included in the discussions of the general description and economic development, but not in the discussions of flood problems or measures to control damages.

Topography

The subregion lies in the broad Willamette-Puget Sound Trough with terrain varying from bare, glacier-covered peaks through forest-covered slopes to fertile lowlands and river deltas. Puget Sound, Georgia Strait, and Hood Canal along with numerous islands, deep-channel passages, inlets and bays are in the center of the trough. As the result of a unique combination of volcanic activity, erosion and glaciation, the region has a wide variation in elevation and topographic features. Elevations vary from 14,408 feet on top of glacier-covered Mount Rainier to 7,954 feet at the peak of Mount Olympus, to sea level on the Sound.

Streams originate from snowfields in the high mountain ranges or from rainfall in forested areas in the foothills and flow into salt water. The river valleys are narrow and steep in the upper reaches and gradually widen as the gradient approaches sea level. Tidal estuaries occur at the mouths of streams.

Climate

The climate, due to variations in elevation, ranges from maritime to Alpine. The prevailing circulation from the Pacific Ocean produces generally mild and wet winters while the summers are comparatively dry and cool. The Cascade Range to the east provides an effective barrier against the invasion of cold arctic air while the Olympic Mountains tend to decrease the intensity of the most severe storms from the west. Annual precipitation, more than 70 percent of which falls during the 6-month period, October through March, varies from less than 20 inches in the rainshadow of the Olympic Mountains to nearly 200 inches in the highest parts of the Cascade Range. Snowfall varies from less than 7 inches at sea level to nearly 600 inches on the highest mountain slopes. Mean temperatures in the lowlands during July vary from 50°F. at night to 75°F. in the afternoon; the December range is from 32°F. to 42°F. Many stations have had temperature readings above 100°F. in the summertime and below 10°F. in the wintertime. The highest temperature recorded was 109°F. at Newhalem in the Skagit Valley; the lowest was -20°F. at Paradise on the slopes of Mount Rainier.

Economic Development

Economically, Subregion 11 comprises the 12 counties in and adjacent to Puget Sound and contiguous waters. Over three-fourths of the 1965 population of 1,904,000 is on the eastern shore of Puget Sound in Snohomish, King, and Pierce counties. Seattle, the largest city, had a population in 1965 of 567,500. Other major cities and their 1965 populations are Tacoma, 152,500; Everett, 50,500; Bremerton, 40,800; Bellingham, 35,500; and Olympia, 19,400. The population pattern reflects the topographical variation. The higher elevations are sparsely populated; the valleys and lowlands bordering eastern Puget Sound are highly urbanized. Most industry, including pulp and paper making, oil refining, food processing, aluminum production, and aircraft manufacturing has developed in the urbanized area.

Productive agricultural land, adequate sites for industry including deepwater access to coastal and world markets, abundant year-round water supply, extensive forests, a skilled labor force, low cost electric power, and marine fishery resources combine to form a basis for residential, industrial, commercial, and agricultural development. Employment totaled about 775,000 in 1966. Twenty-five percent of the working force was engaged in manufacturing and processing and a major portion of these were employed in the aero-space industry. Other employment in 1966 was distributed as 3 percent in agriculture, fisheries,

forestry, and mining; 6 percent in construction; and the remainder in trade and services.

Forest resources support manufacture of lumber, plywood and veneer, pulp and paper, and many other related items. Farm income is principally provided by the sale of livestock and livestock products, vegetables, berries, tree fruits, and field crops. Food processing also provides an important source of income. Forests occupy about 76 percent of the basin and farmland 8 percent. The remaining 16 percent consists of urban areas, roads, and barren lands.

Manufacturing activities were dependent upon resource-based industries until comparatively recent years when diversification provided a more stable base for the economy. Many of the new plants depend upon imported materials from distant sources and the markets for their output extend far beyond the local area. In this category are plants producing transportation equipment, and petroleum, chemical, iron and steel, aluminum, and other light metal products.

The Puget Sound Basin has an excellent transportation linkage with distant population centers, both within the continental United States and abroad. Freight is moved rapidly by air, water, rail, and highway. The Seattle-Tacoma International Airport has a strategic location for polar or great circle route traffic between Pacific Northwest and European and Asian cities. Puget Sound and adjacent waterways are protected from ocean storms and, in general, are very deep. As a result, many harbors can accommodate the largest tankers and grain cargo ships. Major ports are Bellingham, Anacortes, Everett, Seattle, Tacoma, Olympia, and Port Angeles. In addition, there are numerous minor ports. Commercial ferries serve many communities on Puget Sound. Facilities have been developed for deepdraft carriers, commercial fishing vessels, and barges. Three major railroads connect the subregion with the transcontinental rail system. Interstate 5 provides north-south highway transport through the heart of the populated and industrially developed areas. Interstate 90 is the major arterial to the east.

Streams

Major streams, with drainage areas and significant stream-flow data, are listed in table 106, in clockwise order starting in the northeast part of the subregion.

The Nooksack River rises about halfway between the coast and the crest of the Cascade Range. The North, Middle, and South Forks join near Deming to form the main stream. From there, the Nooksack River continues for 37 miles to its outlet on Bellingham Bay. The Lummi River is a distributary of the Nooksack. The Sumas River, a tributary of the Fraser River in Canada, rises north of the Nooksack River and flows northward 19 miles to the International Boundary. Floodwaters of the Nooksack River sometimes overflow into the Sumas Basin.

The Skagit River originates in narrow, precipitous mountain canyons in Canada and flows west and south into the United States where it continues 135 miles to Puget Sound. The stream crosses a broad flood plain in its lower reaches and divides into two principal distributaries each about 9 miles long. Floodwaters sometimes overflow into the Samish River, a minor stream which rises near Sedro Woolley and flows west to Samish Bay.

The North and South Forks of the Stillaguamish River rise in the Cascade Range and join near Arlington to form the Stillaguamish. The upper streams flow through mountain valleys, and the main stem crosses a broad flood plain for 23 miles to Port Susan, an arm of Puget Sound.

The Snohomish River is formed by the junction of its two principal tributaries, the Snoqualmie and Skykomish Rivers. It then flows 23 miles northwesterly, discharging into Possession Sound through several distributary channels, principally Ebey, Union, and Steamboat Sloughs. The North, Middle, and South Forks of the Snoqualmie River join near the town of North Bend to form the main stream. The Snoqualmie then flows 44 miles northwesterly to its confluence with the Skykomish River. The Skykomish River is formed by the junction of its North and South Forks near the town of Index thence flows westerly 28 miles to its confluence with the Snoqualmie River.

The Sammamish River originates in Sammamish Lake, 11 miles east of Seattle, and flows northwesterly to the north end of Lake Washington.

The Cedar River originates high in the Cascade Range and flows 50 miles to discharge into the south end of Lake Washington.

The Green River flows westerly from its source in the Cascades for 50 miles to the vicinity of Auburn. It then flows northerly for 32 miles to Elliott Bay at Seattle. The lower 12 miles of the Green River is known as the Duwamish.

The Puyallup River emerges from glaciers on the western slopes of Mount Rainier and discharges into Commencement Bay at Tacoma. The White and Carbon Rivers are principal tributaries. They drain the north side Mount Rainier glaciers.

The Nisqually River originates in glaciers on the southern and southwestern slopes of Mount Rainier and flows 81 miles northwesterly to Puget Sound.

The Deschutes River rises south of the Nisqually and flows 45 miles northwesterly to Budd Inlet, the southernmost part of Puget Sound at Olympia.

Most Olympic Peninsula rivers (Skokomish, Hamma Hamma, Duckabush, Dosewallips, and Big Quilcene) drop steeply from the Olympic Mountains, flow generally easterly, and discharge into Hood Canal. The Dungeness and Elwha Rivers also originate in the Olympics but drain northward to the Strait of Juan de Fuca.

Recorded data on streamflow are shown in table 106.

Table 106 - Streamflow Summary for Selected Sites, Subregion 11

Stream	Drainage Area (sq. mi.)	Gage	Gage Drainage Area (Sq. Mi.)	Flow in c.f.s.		
				Average	Maximum	Minimum
Nooksack	826 1/	Deming	584	3,217	43,200	502
Skagit	3,105 1/	Mt. Vernon	3,093	16,670	144,000	2,740
Stillaguamish	684					
North Fork		Arlington	262	1,853	30,600	117
South Fork		Granite Falls	119	1,071	32,400	55
Snohomish	1,708	Snohomish	1,720	-	136,000	-
Sammamish	240	-	-	-	-	-
Cedar	188	Renton	186	698	6,640	30
Green-Duwamish	483	Auburn	399	1,306	28,100	81
Puyallup	972	Puyallup	948	3,292	57,000	306
Nisqually	712	La Grande	292	1,385	20,700	0
Deschutes	162	Rainier	90	263	5,620	16
Skokomish	240	Potlatch	227	NA	27,000	125
Hamma Hamma	85	Eldon	51	366	6,010	39
Duckabush	77	Brinnon	67	392	8,960	45
Dosewallips	116	-	-	-	-	-
Big Quilcene	68	-	-	-	-	-
Dungeness	198	Sequim	156	371	6,820	77
Elwha	321	McDonald Bridge	269	1,456	41,600	10

1/ 777 and 2,705 sq. miles, respectively, in U.S.

Flood Characteristics

Flooding generally occurs in the 6-month period, October through March. Prevailing winds during the winter bring moisture-laden air from the Pacific Ocean. Conditions conducive to flood-flows exist when several storms in succession move inland creating a high degree of saturation of the soil, increasing the moisture

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content of the snowpack, and raising the rivers to bankfull condition. If an intense, warm storm with a high rate of precipitation then occurs, flooding is inevitable. Where headwaters are at high elevations, the combination of rising temperature and heavy rainfall cause rapid snowmelt which adds to the runoff. Winter floods normally last 2 or 3 days with river discharges increasing from a relatively low base flow to flood stage in a few hours. Occasionally, spring high water is experienced on rivers with high altitude drainage basins and a deep snowpack. These occur during April to June as a result of rising temperatures which cause rapid melting.

HISTORY OF FLOODING

Major floods on various streams of the subregion are listed in table 107. Discharges shown are those actually measured at the time of the flood; however, damages given are those which would occur if the flood were repeated under present day development and price levels. In some cases the discharge would have been reduced by subsequent upstream regulation, but the damages correspond with the stated flows. Data are from the PSAW Report. (1)

The Nooksack River has exceeded zero damage flow (19,000 cfs at Deming) 34 times and major damage flow (25,000 cfs) 16 times since 1932. The greatest recorded flow, 43,200 cfs, occurred in February 1951. This flood inundated 26,800 acres of which 17,700 acres were farmland. Damages occur to farmland crops, and buildings, and to portions of Everson, Lynden, Ferndale, and Marietta. Part of the flow crossed the divide into the Sumas River Basin where 2,000 acres and the entire town of Sumas were inundated. An estimated flow of 49,300 cfs occurred in February 1932.

The Skagit River has exceeded zero damage flow (60,000 cfs at Concrete) 29 times since 1924. The greatest recorded flow, 260,000 cfs, occurred in November 1909. The levee at Burlington was breached and most of the flood plain downstream, including the Samish River Basin, was inundated. A flood in December 1921 was nearly as large; levees failed between Burlington and Mount Vernon. Floods of 154,000 cfs in November 1949 and 139,000 cfs in February 1951 also caused levee failures. Much larger flows are estimated to have occurred in the previous century--350,000 cfs in 1856 and 500,000 cfs about 1815.

Table 107 - Major Floods, Subregion 11

Stream	Date	Discharge (c. f. s.)	Measured near	Damages under 1/ Present Conditions
Nooksack	Feb 1951	43,200	Deming	\$ 2,256,000
	Nov 1955	38,500		1,931,000
Skagit	Nov 1909	260,000	Concrete	22,170,000
	Dec 1921	240,000		20,820,000
	Nov 1949	154,000		9,090,000
	Feb 1951	139,000		16,650,000
Stillaguamish	Feb 1932	65,000	Arlington	890,000
	Feb 1951	61,000		705,000
	Nov 1959	59,600		655,000
Snohomish	Feb 1951	136,000	Snohomish	7,980,000
	Nov 1959	113,300		6,730,000
Cedar	Jan 1903	10,200	Landsburg	Not available
	Nov 1906	12,400		Not available
	Dec 1933	7,520		1,188,000
	Feb 1951	6,200		597,000
	Nov 1959	4,840		225,000
	Jan 1965	4,640		216,000
Sammamish	Feb 1951	1,900	Bothell	0
	Jan 1956	1,910		0
Green-Duwamish	Dec 1933	24,000	Auburn	Not available
	Nov 1959	28,100		230,000
	Jan 1965	11,400 2/		230,000
Puyallup (No major floods since Mud Mountain Dam constructed, 1943)				
Nisqually	Dec 1933	42,000	McKenna	Not available
	Nov 1959	20,500		40,000
	Dec 1964	22,300		50,000
	Jan 1965	25,700		140,000
Deschutes	Dec 1955	6,080	Olympia	90,000
	Nov 1962	5,000		30,000
	Jan 1964	6,650		130,000
Skokomish	Nov 1955	27,000	Pottlatch	125,000
	Apr 1959	23,600		71,000
	Nov 1959	22,100		56,000
	Jan 1961	26,400		114,000
Hamma Hamma	Nov 1955	5,810	Eldon	1,600
	Jan 1960	5,410		1,100
	Jan 1961	4,920		1,000
Duckabush	Nov 1949	8,960	Brinnon	30,000
	Jan 1960	6,500		6,000
Dosewallips	Nov 1934	10,900	Brinnon	108,000
	Nov 1949	13,200		137,000
	Nov 1955	8,050		56,000
Big Quilcene	Dec 1966	2,760	Quilcene	2,040
Dungeness	Nov 1949	6,820	Sequim	48,000
	Nov 1955	6,750		43,000
Elwha	Nov 1897	41,600	McDonald Bridge	51,000
	Mar 1901	33,600		29,000
	Nov 1949	30,000		21,000

^{1/} With historical precipitation and runoff but flow modified by existing storage.

^{2/} Regulated by Howard Hanson Dam, unregulated peak would have exceeded 1933 flood.

The Stillaguamish River has exceeded zero damage flow (37,000 cfs at Arlington) 43 times and major damage flow (53,000 cfs) nine times since 1931. The largest flow was 65,000 cfs in February 1932. In November 1959, a flood of 59,600 cfs inundated Stanwood. In December 1967, tide dikes near Stanwood failed and 620 acres were covered with salt water.

The Snohomish River has exceeded zero damage flow (43,000 cfs at Snohomish) 55 times since 1942. The greatest recorded flow, 136,000 cfs, took place in February 1951 when 35,000 acres of farmland were inundated and a number of homes and roads damaged. A flood of 113,300 cfs occurred in November 1959.



Snohomish River-Eby Slough, November 1959. (USCE)

The Cedar River has exceeded major damage flow (4,200 cfs at Landsburg) 17 times since 1895. The greatest recorded flow since 1911, 7,520 cfs, took place in December 1933, when the entire downstream flood plain of 800 acres was inundated. Flows of 12,400 cfs in November 1906 and 10,200 cfs in January 1903 have been recorded.

Prior to 1916 when the level of Lake Washington was lowered the entire Sammamish flood plain was a swamp. The largest flows since 1939 are shown in table 107. Historical floods on the

Sammamish River would have a much lesser effect today because of the channel improvements made in 1964.

From 1932 through 1959, overbank floods on the lower Green River occurred 29 times. The largest floods, 28,100 and 24,000 cfs at Auburn, occurred in November 1959 and December 1933, respectively. Since completion of Howard A. Hanson Dam in 1962, major damage flow of 12,000 cfs at Auburn has not been exceeded.

Major floods on the Puyallup River were recorded 18 times at Puyallup between 1914, when the gage was established, and 1943, when Mud Mountain Dam was completed. The two largest floods occurred on the 10th and 21-22nd of December 1933 with flows of 57,000 and 45,700 cfs, respectively. It is estimated that the natural peak of the flood of January 1965 would have been 53,000 cfs.

The river has not exceeded zero damage flow (45,000 cfs at Puyallup) since construction of Mud Mountain Dam, and levees and channel improvements. However, upstream in the vicinity of Orting, the 5,000-cfs capacity of the streambed has been exceeded 13 times in the same period.

The Nisqually River has exceeded zero damage flow (18,000 cfs at McKenna) four times but not major damage flow (26,000 cfs) since 1948. An estimated flood of 42,000 cfs in December 1933 inundated most of the 3,000-acre delta.

The Deschutes River has exceeded zero damage flow (3,500 cfs at Olympia) 14 times and major damage flow (5,400 cfs) twice since 1945. The greatest recorded flood was 6,650 cfs in January 1964. The largest recorded flood on the Hamma Hamma River was 5,810 cfs in November 1955. It has exceeded zero damage flow (4,100 cfs at Eldon) six times since 1951.

The Duckabush River has exceeded zero damage flow (4,200 cfs near Brinnon) 26 times and major damage flow (7,000 cfs) once since 1938. The largest recorded flood was 8,960 cfs in November 1949.

The Dosewallips River has exceeded zero damage flow (4,200 cfs near Brinnon) 23 times and major damage flow (8,000 cfs) three times since 1931. The largest recorded flood was 13,200 cfs in November 1949.

Peak flows on the Big Quilcene River are not recorded. An estimated flood of 2,760 cfs at Quilcene in December 1966 exceeded zero damage flow of 1,900 cfs but not major damage flow of 3,000 cfs.

The Dungeness River has exceeded zero damage flow (4,000 cfs at Sequim) 12 times and major damage flow (6,000 cfs) three times since 1923. The largest recorded flood was 6,820 cfs in November 1949.

The Elwha River has exceeded zero damage flow (9,000 cfs near Port Angeles) 40 times since 1897. The largest recorded flood was 41,600 cfs in November 1897. Floods of 30,000 cfs occurred in November 1949 and 21,700 cfs in November 1962.

PRESENT STATUS

Existing Measures

Flood Control Storage

Ross Dam was constructed by the city of Seattle in 1940 at river mile 105 on the Skagit River. In 1949, the dam was raised to its present height, forming a reservoir of 1,052,000 acre-feet of usable storage. Since 1953, when spillway gates were installed, 120,000 acre-feet of joint-use storage have been available for flood control. This provision was incorporated into the FPC license in 1964. Storage is utilized when discharge on the Skagit at Concrete is forecast to exceed 90,000 cfs.

Howard A. Hanson Dam at river mile 64.5 on the Green River, constructed by the Corps of Engineers in 1962, provides 106,000 acre-feet of flood control storage and a summer conservation pool for maintaining minimum streamflows for fish habitat enhancement.

Mud Mountain Dam at river mile 29.6 on the White River, a tributary to the Puyallup River, was constructed by the Corps of Engineers in 1943. The reservoir has a capacity of 106,000 acre-feet and is operated exclusively for flood control.

Upper Baker Dam at river mile 9.3 on the Baker River, a tributary of the Skagit River at Concrete, has a provision in the Federal Power Commission license that 84,000 acre-feet of flood control storage may be requested by the Federal Government, provided that suitable arrangements are made for compensating Puget Sound Power and Light Company for the power losses incurred. Congress has not authorized such compensation and the space has not been available for flood control.

Power reservoirs which have made incidental regulation of floodflows include Alder Reservoir on Nisqually River, Lake Cushman on the North Fork of Skokomish River, and Lake Mills on Elwha River. No space in any of these reservoirs is planned for

flood control, but any that happens to be available at the time of flooding is used and the reservoirs are drawn down in advance when flood conditions are forecast. Such incidental regulation reduces damages but does not assure control at all times.

There are 1,890 retaining ponds and small reservoirs with a total of 7,200 acre-feet of storage on minor tributaries.

Levees

Table 108 lists major levees on which information is available. Generally, construction has been carried out by diking districts and private interests, with Federal participation limited to the Snohomish, Puyallup, and Dungeness Rivers. In addition to those shown in the table, there are 273 miles of levees on minor tributaries.

Table 108 - Existing Levees, Subregion 11

Stream	Location	Description
Nooksack	North Cedarville to mouth	42.4 miles of levee along 36 miles of river including Lummi River, a distributary.
Skagit	Burlington to mouth	66 miles of levee on main stem and North and South Forks, 6 miles on Smaish River, and 39 miles on Swinomish Channel and Padilla and Skagit Bays.
Stillaguamish	Florence to mouth	Levees and tide dikes on main stem and Hat Slough.
Snohomish	Snohomish River proper	67.6 miles of levee on main stem including recent Soil Conservation Service projects at French Creek and Marshland.
	Snoqualmie River	1.5 miles of levee on South Fork at North Bend. 1.3 miles of levees on Raging River at Fall City. Levee 1 mile long on left bank of main stem 1 mile downstream from Fall City. 1.2 miles of levee on Tolt River at Carnation.
	Skykomish	Levee 2,000 feet long at Skykomish. Levee at Index. Levee 1.3 miles long at Startup.
Sammamish	Entire length	Segments of low embankment from channel excavation. Possible base of future levee.
Green	Below Kent	11.4 miles of levee.
Puyallup	Main stem above Orting to near mouth	6.8 miles of levee above Orting; 9.2 miles of levee, Orting to Sumner; 15.5 miles of levee below Sumner; all on 25 river miles.
	Carbon River	10.7 miles of levee on 7.2 river miles.
	White River	13 miles of levee on 18.8 river miles.
Skokomish	Near mouth	Tide dikes.
Hamma Hamma	Near mouth	600-foot levee on right bank 4,000 feet upstream from U.S. 101.
Dosewallips	Near mouth	500-foot levee on right bank at Dosewallips State Park.
Big Quilcene	Near mouth	Levees both sides main stem at Quilcene. Tide dikes on Quilcene Bay.
Dungeness	Near mouth	Levee 2.5 miles long on right bank. Corps of Engineers, 1964. 325-foot levee on left bank downstream from river mile 0.8, Clallam County, 1964.
Eiwha	Near mouth	1,000-foot levee on left bank at community called The Place. Clallam County, 1964.

Flood Control Channels

Flood control channels described here do not include incidental channel improvement in connection with levee and bank protection works.

No changes have been made in the Nooksack River or major tributaries, but three tributary creeks which previously caused flooding at Deming are controlled by a high-capacity interception channel. Miscellaneous widening and straightening have been carried out on the Sumas River.

On the Stillaguamish River, Cook Slough was straightened in 1939 over a distance of 1,800 feet and a concrete weir 275 feet long constructed at the head of the slough.

The Snohomish River receives minor flood control benefits from navigation channel improvements on its lower 4 miles.

In 1964, the Sammamish River was widened and deepened throughout its 14-mile length except for a control section at the outlet of Lake Sammamish.

The Cedar River was diverted into Lake Washington by means of a stabilized channel of 9,500 cfs capacity in 1912.



Channel work on the Sammamish River. (USCE)

The Green-Duwamish River receives minor flood control benefits from navigation channel improvements on its lower 6 miles.

When the White River was diverted into the Puyallup River in 1906, King and Pierce Counties formed the Inter-County River Improvement District and improved the channel downstream to river mile 3 on the Puyallup. In 1950, the Corps of Engineers made channel improvements and constructed levees downstream from river mile 3 to provide a capacity of 45,000 cfs.

On the Elwha River, the head of the East Channel at river mile 1.5 has been plugged with a gravel fill, diverting normal and moderately high flows into the west channel.

On minor tributaries, improvements have been made to 167 miles of stream channel.

Flood Forecasting and Emergency Operation

Estimates of impending peak floodflows or stages and the expected time of occurrence are prepared by the River Forecasting Unit at Portland, Oregon, and telephoned to the Seattle River District Office. The River District Office in turn notifies the Corps of Engineers, Geological Survey, the Washington Department of Water Resources, the Federal Office of Emergency Planning, and State and County Civil Defense organizations via NAWAS, the National Warning System. Teletype bulletins are sent by the River District Office to the national news services and principal radio and television broadcasting companies in Seattle. The news services are asked to forward the information to newspaper and broadcasting subscribers in the areas where flooding is anticipated.

Along with the above routine contacts, the River District Office specifically telephones the county flood coordinator if one has been designated by the county concerned. At present, these are as follows:

Whatcom County	- County Engineer
Skagit County	- County Engineer
Snohomish County	- Civil Defense Director
King County	- County Engineer Flood Control Division
Lewis County	- County Engineer

In addition to these channels of information, the Corps of Engineers in Seattle receives flood forecasts directly from the Portland River Forecasting Unit for the benefit of flood engineers assigned to specific areas for flood emergencies. Table 109 shows

these areas, the location of important gages, the zero damage stage and flow at which flooding is considered to begin, and the local official contacted by the flood engineers.

Table 109 - Flood Emergency Areas, Subregion 11

Area	Gage	Zero Damage		Local Contact
		Stage (Ft.)	Flow (c.f.s.)	
Nooksack	Deming	12.0	19,300	Whatcom County Engineer
Skagit	Mt. Vernon	18.6	51,000	Skagit County Engineer
Stillaguamish	Arlington	16.0	37,000	Snohomish County Civil Defense Dir.
Snohomish	Snohomish	25.0	43,000	Do.
Skykomish	Gold Bar	15.0	40,000	Do.
Snoqualmie	Carnation	54.0	22,600	King County Engineer
Cedar	Landsburg	5.4	4,200	Do.
Sammamish	Redmond	-	1,700	Do.
Green	Auburn	63.0	10,100	Do.
Puyallup	Puyallup	-	45,000	Pierce County Engineer
Nisqually	McKenna	11.4	18,000	Do.
Deschutes	Olympia	7.4	3,500	Thurston County Engineer
Skokomish	Potlatch	9.2	13,000	Mason County Engineer
Hamma Hamma	Eldon	6.5	4,100	Do.
Duckabush	Brinnon	6.8	4,200	Jefferson County Engineer
Dosewallips	Brinnon	6.5	4,200	Do.
Big Quilcene	Quilcene	-	1,900	Do.
Dungeness	Sequim	6.4	4,000	Clallam County Engineer
Elwha	Port Angeles	15.5	9,000	Do.

Watershed Protection

More than 506,000 acres of cropland in Subregion 11 have had effective combinations of practices applied which reduce erosion and sedimentation and assist in the reduction of floods. The most effective practices include conservation cropping systems on 210,000 acres, use of crop residue on 32,000 acres, and 2,446 miles of drainage conduits or ditches. Forest land treatment measures to reduce sediment and floodflows include the seeding and gully stabilization on 3,500 acres of eroding soils and the rehabilitation of 260 miles of roads and trails. Rangeland practices of particular significance include seeding 2,500 acres to grass, brush control on 9,700 acres, and reduction of excessive grazing on 27,700 acres.

The soils of Subregion 11 are estimated to have a water holding capacity of at least 2,705,000 acre-feet, an average of 3.84 inches over the entire watershed. This storage is effective in retarding runoff to an extent dependent upon land treatment and weather conditions. Additional information on land treatment is given in Appendix VIII, "Land Measures and Watershed Protection."

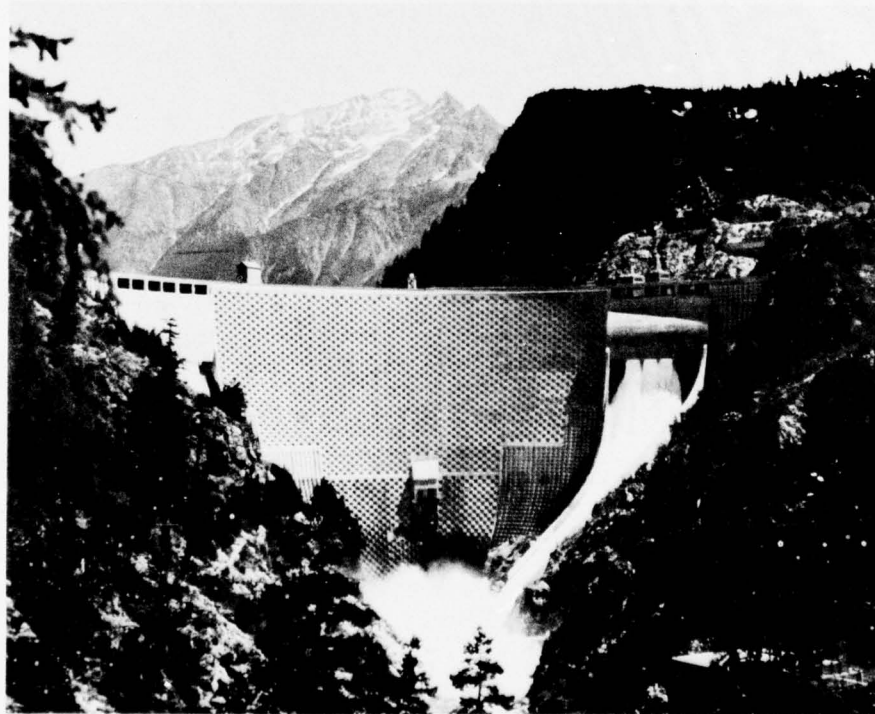
Flood Plain Regulation Program

The zoning ordinances of Skagit, Snohomish, and King Counties contain classifications applicable to flood plains. Zone mapping is gradually being accomplished in the Skagit, Stillaguamish, Snohomish, Cedar, and Green-Duwamish basins. Flood plain information studies are available for the Nooksack, Sumas, Skagit, Stillaguamish and Snohomish Rivers, and for the Cedar River at Renton.

Accomplishments

Storage

Ross Dam reduces the severity of flooding on the Skagit River, but because of the limited portion of the drainage area it controls, cannot achieve complete control. It is estimated that the storage behind Ross Dam would have reduced the floods of 1909, 1917, and 1921 from 220,000 cfs to 187,000 cfs; 195,000 cfs to 192,000 cfs; and 210,000 cfs to 194,000 cfs, respectively.



Ross Dam on the Skagit River. (Seattle City Light)



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY
**EXISTING & POTENTIAL
FLOOD CONTROL FACILITIES**
PUGET SOUND SUBREGION II

1970

FIGURE 28

Howard A. Hanson Dam regulates floods to an estimated 600-year frequency at the damsite with releases adjusted to maintain a within-bank flow of 12,000 cfs at Auburn.

Mud Mountain Dam on the White River regulates 100-year frequency floods to within-bank flows of 20,000 cfs on the White River downstream from Auburn and 45,000 cfs on the 10.4 miles of Puyallup River downstream from Sumner.

Levees

The existing levees along the Nooksack River are 3 to 6 feet high and provide varying degrees of protection. All are likely to be overtopped on an average of every 5 years. A levee along the right bank near Everson prevents the Nooksack from overflowing through the town into the Sumas Valley. This levee protects to about a 4-year flood, but serious overflow into the Sumas Valley does not occur until the Nooksack flow reaches about 40,000 cfs (about 10-year frequency).

On the Skagit River, levees provide partial protection for 45,000 acres. Generally, protection is against 3- to 8-year frequency floods but the 7.5 mile left bank levee from Burlington to Mount Vernon protects against 14-year frequency floods. Tide dikes along Swinomish Channel and Padilla and Skagit Bays give substantially complete protection against high tides except when breached by failure of river levees.

Levees on the Stillaguamish River downstream from Silvana protect against 3-year frequency floods. In combination with tide dikes, 620 acres are protected in the vicinity of Stanwood.

On the Snohomish River proper, 20,212 acres are partially protected by levees. Protection is generally against 1- to 5-year frequency floods, except that near the river mouth 1,283 acres on Smith Island are protected against 40-year frequency floods and 405 acres on the right bank of Ebey Slough near Marysville are protected against 200-year frequency floods. The general low degree of protection is not a true indication of potential damage because maximum flooding occurs in the winter with a minimal effect on agricultural protection. At French Creek and Marshland, two major farming areas totalling 11,600 acres have protection on the order of 25-year frequency against the more significant spring flooding. On the Snoqualmie River levees on the South Fork protect North Bend against 50-year frequency floods, the Raging River levees protect Fall City and agricultural lands. The main stem levee below Fall City protects 600 acres of farmlands, and the levees on the Tolt River provide

moderate protection to Carnation and adjacent agricultural lands. On the Skykomish River, levees protect Skykomish against 5- to 10-year frequency floods and Index against 2- to 3-year floods. The levee at Startup prevents 50-year frequency floods from overflowing into the Wallace River.

Levees on the Green River in conjunction with control by Howard A. Hanson Dam protect 12,000 acres of agricultural land and 5,600 acres of land in residential and commercial use. However, at the regulated flows of 12,000 cfs at Auburn, the levees have no freeboard and sustain some damages.

On the Puyallup River below Sumner and the White River from Auburn to Sumner, the levees and channel improvement, together with control by Mud Mountain Dam, protect 7,000 acres and Sumner, Puyallup, Fife, and Tacoma against 100-year frequency floods. Levees from Orting to Sumner partially protect about 9,000 acres but only against 10-year frequency floods. Upstream from Orting, about 1,500 acres are protected against 1.5-year frequency floods.

Levees on the Nisqually provide moderate protection to Mount Rainier National Park facilities, protect McKenna against 20-year frequency floods, and, together with tide dikes, protect 3,000 acres of farmland in the delta against 7-year frequency floods.

Moderate protection to lowlands at the mouth of the Skokomish is provided by tide dikes.

The levee on the Hamma Hamma River protects 30 acres of pasture and cultivated land against minor floods.

The levee on the Dosewallips River at the State park serves chiefly as a training dike and has little value for flood prevention.

Levees on the Big Quilcene River protect 40 acres at Quilcene from 1- to 3-year frequency floods. Dikes on Quilcene Bay protect part of the delta from high tides.

The right bank levee on the Dungeness River protects 954 acres including Dungeness and small farms from 200-year frequency floods. The levee on the left bank is 5 feet lower and provides moderate protection to a residential area.

The levee at the mouth of the Elwha River protects the community of The Place against 25-year frequency floods.

Howard A. Hanson Dam regulates floods to an estimated 600-year frequency at the damsite with releases adjusted to maintain a within-bank flow of 12,000 cfs at Auburn.

Mud Mountain Dam on the White River regulates 100-year frequency floods to within-bank flows of 20,000 cfs on the White River downstream from Auburn and 45,000 cfs on the 10.4 miles of Puyallup River downstream from Sumner.

Levees

The existing levees along the Nooksack River are 3 to 6 feet high and provide varying degrees of protection. All are likely to be overtopped on an average of every 5 years. A levee along the right bank near Everson prevents the Nooksack from overflowing through the town into the Sumas Valley. This levee protects to about a 4-year flood, but serious overflow into the Sumas Valley does not occur until the Nooksack flow reaches about 40,000 cfs (about 10-year frequency).

On the Skagit River, levees provide partial protection for 45,000 acres. Generally, protection is against 3- to 8-year frequency floods but the 7.5 mile left bank levee from Burlington to Mount Vernon protects against 14-year frequency floods. Tide dikes along Swinomish Channel and Padilla and Skagit Bays give substantially complete protection against high tides except when breached by failure of river levees.

Levees on the Stillaguamish River downstream from Silvana protect against 3-year frequency floods. In combination with tide dikes, 620 acres are protected in the vicinity of Stanwood.

On the Snohomish River proper, 20,212 acres are partially protected by levees. Protection is generally against 1- to 5-year frequency floods, except that near the river mouth 1,283 acres on Smith Island are protected against 40-year frequency floods and 405 acres on the right bank of Ebey Slough near Marysville are protected against 200-year frequency floods. The general low degree of protection is not a true indication of potential damage because maximum flooding occurs in the winter with a minimal effect on agricultural protection. At French Creek and Marshland, two major farming areas totalling 11,600 acres have protection on the order of 25-year frequency against the more significant spring flooding. On the Snoqualmie River levees on the South Fork protect North Bend against 50-year frequency floods, the Raging River levees protect Fall City and agricultural lands. The main stem levee below Fall City protects 600 acres of farmlands, and the levees on the Tolt River provide

Flood Control Channels

The weir and channel straightening on Cook Slough have substantially eliminated flooding on that branch of the Stillaguamish River.

Improvement of the Sammamish River channel enables it to carry flows of from 1,500 cfs at its upstream end to 1,900 cfs downstream, equivalent to protection against 5-year frequency floods. Floods in excess of a 10-year frequency winter flood or 40-year frequency spring flood inundate most of the flood plain.

The channel which carries the Cedar River into Lake Washington protects the Renton area against 100-year frequency floods.

As noted under accomplishments of levees, channel improvements from Auburn on the White River to the mouth of the Puyallup River protect 7,000 acres and Sumner, Puyallup, Fife, and Tacoma against 100-year frequency floods.

The diversion of flow from the east channel of the Elwha to the west channel protects agricultural land on the right bank from minor floods.

Comprehensive Watershed Projects

Six completed comprehensive watershed projects protect some 40,000 acres of agricultural land from flood damages and reduce average annual damages in those areas by \$566,000. Remaining damages are \$125,000.

Flood Problems

In the United States portion of the basins, the flood plain of the Nooksack and Sumas Rivers comprises 49,000 acres including lands partially protected by levees. Most of the flood plain is agricultural land in pasture and hay, but portions of Lynden, Ferndale, Everson and Marietta, and all of Sumas are subject to flooding. Of this area, 5,000 acres are in the Sumas Valley, and additional lands in Canada are flooded by major floods on Sumas River. Some lands are flooded almost every year, and major damage occurs about every 2 years. Five-year frequency floods overtop the levee protecting Everson and overflow into the Sumas Valley. Twelve-year frequency floods inundate 26,800 acres, of which 17,700 acres are agricultural, including 2,000 acres in the Sumas Valley and the entire town of Sumas, and parts of Everson, Lynden, Ferndale, and Marietta. Average annual damages amount to \$853,000 of which about 56 percent are rural and 44 percent urban.

In the Skagit-Samish Valleys, 90,000 acres of agricultural and urban land, including high value farmlands, parts of Hamilton, Sedro Woolley, Mount Vernon, Conway, and La Conner, and all of Burlington, are subject to flooding. Of this area, 68,000 acres are downstream from Sedro Woolley, the upstream end of the extensive levee system. Some flooding occurs annually upstream from Sedro Woolley and extensive flooding occurs about every other year. Below Sedro Woolley, levee overtopping starts with 3-year frequency floods and, with 14-year frequency floods, most levees are subject to failure including the left bank levee from Burlington to Mount Vernon. About a 17-year frequency flood would overtop the levee at Burlington, overflow into the Samish Valley, breach the tide dikes, and inundate parts of Burlington, Mount Vernon, and La Conner. A 100-year frequency flood would inundate most of the flood plain from Burlington to Swinomish Channel. The pattern of flooding cannot be predicted exactly for any given discharge because of variations in duration of high flows and of location of initial levee breaks. Average annual damages amount to \$3,020,000 of which 57 percent are rural and 43 percent urban.

In the Stillaguamish Valley, 12,600 acres, mostly agricultural land in pasture and row crops but also including all of Silvana and Stanwood, are subject to flooding. Of this area, 7,000 acres are downstream from Silvana. Some flooding occurs about every 2 years, and floods of 4-year frequency overtop levees. Six-year frequency floods cause major damage, and 10-year frequency floods cause general inundation and closure of highways. Average annual damages amount to \$256,000 of which 39 percent are rural and 61 percent urban.

In the Snohomish Valley, the flood plain includes 59,000 acres. Most is agricultural land but several urban areas also are included. On the Snohomish River proper, the flood plain comprises 25,000 acres including 18,000 acres of agricultural land and parts of Everett and Marysville. On the Snoqualmie River it comprises 23,000 acres including parts of North Bend, Snoqualmie, and Carnation. On the Skykomish River it comprises 11,000 acres including parts of Index, Gold Bar, Startup, Sultan, and Monroe. Some flooding occurs nearly annually on the Snohomish and Snoqualmie and about every 2 years on the Skykomish. Overtopping of levees occurs frequently; nearly all levees are overtopped and general flooding takes place with 5-year frequency floods. Nine-year frequency floods inundate 35,000 acres. Flooding at the mouth of the Snohomish is frequently aggravated by high tides. Average annual damages amount to \$2,310,000 of which 26 percent are rural and the remainder are urban, including transportation.

In the Cedar River Valley, 800 acres are subject to flooding (including parts of Landsburg, Maple Valley, and Renton). Some flooding occurs annually, and major damage occurs with 7-year frequency floods. A 100-year frequency flood would inundate nearly the entire flood plain, but would not exceed the capacity of the improved channel in the lower mile of the river through Renton. Average annual damages amount to \$117,000, of which over three-fourths are urban.

In the Sammamish Valley, 3,600 acres of land are subject to flooding. Most of this area is in vegetable farms and there is some recreational development. A 10-year frequency flood inundates most of the flood plain, but this usually occurs prior to planting and damages are minimal. Flooding of planted lands would occur with a 40-year frequency spring flood. Average annual damages amount to \$5,000.



Flooding along the Snoqualmie River, November 1959. (USCE)

The flood plain of the Green-Duwamish River between Seattle and Auburn comprises 17,800 acres. Of this area, 9,600 acres are in agriculture, chiefly pasture and vegetables. The remainder is industrial, commercial, and residential, including parts of Auburn, Kent, Tukwila, and Renton. The maximum controlled flow at Auburn, regulated by Howard A. Hanson Dam, is 12,000 cfs. At this flow the river surface is at the top of existing dikes

in many places, creating a potentially hazardous situation. At the same time interior drainage is impounded, causing inundation of large parts of the flood plain. A system of drainage channels and pumping plants to relieve the interior drainage problems is under construction. However, the pumped discharge and the maximum flow as regulated by Hanson Dam cannot both be accommodated by the existing river channel and dikes. Average annual damages amount to \$325,000, mostly to agricultural lands and industrial and residential developments.

In the Puyallup-White Valley, the flood plain comprises 17,500 acres including agricultural land, and portions of Orting, Sumner, Puyallup, Fife, and Tacoma. Of this area, about 1,500 acres are along Puyallup River above Orting, 9,000 acres between Orting and Sumner, 6,150 acres below Sumner, and 850 acres along the White River between Auburn and Sumner. An 11-year frequency flood overtops levees between Sumner and Orting, and some inundation occurs above Orting every year or two. The problem at Orting is aggravated by flooding of the Carbon River tributary. Average annual damages amount to \$100,000 of which 20 percent are rural and the balance urban, including transportation.

In the Nisqually Valley 9,000 acres, including 3,000 acres of agricultural lands in the delta, facilities at Mount Rainier National Park, and part of McKenna, are subject to flooding. Some flooding of the delta occurs about every 8 years with overtopping of levees. A 21-year frequency flood would cause inundation of part of McKenna and a 100-year flood most of the delta. Average annual damages amount to \$31,000 of which one-third are agricultural and the remainder are urban and transportation.

In the Deschutes Valley 2,700 acres, of which 1,200 are developed, and industrial and residential sections of Tumwater are subject to flooding. Some flooding occurs about every 2 years and 6-year frequency floods cause major damage. Average annual damages amount to \$26,000 approximately equally divided among urban, agricultural, and transportation.

In the Skokomish Valley 4,600 acres, of which 1,600 are in agriculture, mostly pasture and hay, are subject to flooding. Some flooding occurs annually and major damage every 2 or 3 years. Deposition of gravel and debris in the main stem by tributary streams aggravates flooding. Average annual damages amount to \$27,000.

In the Hamma Hamma Valley 66 acres, including 26 acres in pasture, a dairy farm, and vacation cabins are subject to flooding. Some flooding occurs about every 3 years and major damage about every 17 years. Average annual damages amount to \$800.

In the Duckabush Valley, 70 acres of land and several summer homes are subject to flooding. Some flooding occurs about every 2 years and major damage about every 11 years. Average annual damages amount to \$3,000.

In the Dosewallips Valley 250 acres, including 47 acres within Dosewallips State Park, homes, and truck gardens are subject to flooding. Some flooding occurs about every 2 years and major damage about every 11 years. Average annual damages amount to \$11,600.

In the Big Quilcene Valley 171 acres and several homes, including part of Quilcene, are subject to flooding. Most of the homes are on the right bank which is 5 feet higher than the left. Some flooding occurs every 2 or 3 years and major damage about every 7 years. Average annual damages amount to \$8,500, nearly all urban.

In the Dungeness Valley, 2,900 acres including pastureland, scattered buildings, and the town of Carlsborg are subject to flooding. Some flooding occurs about every 4 years and major damage about every 8 years. Average annual damages to agricultural lands and improvements, transportation facilities, campgrounds, and utilities amount to \$24,000.

In the lower 2 miles of the Elwha Valley, 750 acres of mostly agricultural land are subject to flooding. Some flooding occurs every year or two. A 26-year frequency flood would overtop a levee on the left bank near the river mouth protecting a residential community. Average annual damages amount to \$4,000.

Throughout the subregion, an estimated 152 miles of stream-bank are subject to serious erosion, which, at an estimated average annual lateral retreat of 1.6 feet, causes an annual land loss of 30 acres. Eroded material is deposited on the flood plains and estuaries or carried into Puget Sound and adjacent water bodies. Present average annual erosion damages, including land loss and sedimentation costs, are estimated at \$115,000.

Lands subject to flooding in tributary areas comprise 277,000 acres of cropland, 23,000 acres of forest land, and 17,000 acres of range and pasturelands. In addition, much of the agricultural lands have drainage problems due to lack of outlets for the floodwaters. Average annual damages in these areas amount to \$8,822,000.

PROJECTIONS AND NEEDS

Economic Trends

The population of Subregion 11, which now is more populous than any of the other subregions, is expected to grow at a slightly greater rate than the region as a whole. By 2020, the 1966 population of 1,965,000 is forecast to increase to 4,448,000 as projected in Appendix VI, Economic Base and Projection. Projections made by Consulting Services Corporation for the Puget Sound and Adjacent Waters Comprehensive Water Resource Study (PSAW) forecast a 2020 population of 6,809,000. (1) Consulting Services Corporation projected gross regional product to increase at about 4.4 percent to \$68.25 billion by 2020. They did not project per capita or total personal income, the economic parameters that have been used for projecting urban and urban-related damages in the Columbia-North Pacific Study. However, there is a close correlation between growth of total personal income and of gross regional product and since the projections for GRP growth as used in the PSAW study do not differ greatly from the projections of total personal income growth for Subregion 11 of C-NP, the future flood control needs as developed for PSAW are considered appropriate for use in C-NP. This consideration is further strengthened by the large amount of economic data developed by Consulting Services Corporation.

The greatest rate of population growth is expected to occur in river basins in the vicinity of the Tacoma-Seattle-Everett metropolitan area - the Stillaguamish, Snohomish, Cedar, Green-Duwamish, and Puyallup - and on the west side of Hood Canal. Throughout the subregion, employment in the basic industries of agriculture and forestry, wood products and manufacturing, fishing, and mining is expected to decline. Other industries in which employment will decline because of more efficient use of labor are chemicals, transportation, and communication. The paper and petroleum industries are expected to remain approximately constant in numbers employed. Increased employment will take place in food processing, the primary metals industry, nonmetallic minerals, miscellaneous manufacturing, construction, trade and services.

Land Use Trends in Flood Plain

The most noticeable change in land use will consist of a steady reduction in farm acreage, particularly in the river basins adjacent to the Tacoma-Seattle-Everett metropolitan area. The amount of land in farms is expected to decrease from 1,053,000 acres in 1963 to 460,000 acres by 2020. There will be a reduction

in hay and silage production, but an increase in vegetables, berries, cattle, and poultry. Most of the remaining farming area will be found in the Nooksack and Skagit basins. Elsewhere, urban and industrial development will gradually occupy the valleys on the periphery of existing growing communities.

Future Flood Damages

Future flood damages are expected to increase parallel to economic development on the flood plains which in turn is expected to parallel the economic development of the subregion. Determination of the future damages shown in table 110 has therefore been based on projections of population growth, income and expenditures, and land use patterns. Separate estimates were made of agricultural and nonagricultural damages. The nonagricultural component was further broken down into several categories.

Growth in agricultural flood damages was based on projections of production and value of major agricultural products made for the PSAW study by the Economic Research Service. Feed crops are expected to decline at an annual average rate of about 2.8 percent; food crops are expected to increase at a rate of about 1.9 percent per year and livestock at about 1.5 percent annually. In projecting the growth in the value of agricultural production in each of the flood plains, the following factors were considered: Acres of productive agricultural land in the flood plain, present and future crop patterns, idle or fallow lands to be brought into production, agricultural land lost to urban and other types of encroachment, and flood plain management practices.

Table 110 - Present and Future Average Annual Damages ^{1/}, Subregion 11

Stream Basin	Present, \$1,000			1980	2000	2020
	Rural	Urban	Total			
Nooksack-Sumas	480	373	853	1,210	1,970	3,350
Skagit-Samish	1,720	1,300	3,020	4,340	7,060	12,030
Stillaguamish	100	156	256	380	690	1,310
Snohomish	601	1,709	2,310	3,520	6,370	13,100
Cedar-Sammamish	4	113	122 ^{2/}	210	450	980
Green-Duwamish			325 ^{2/}	570	1,250	2,760
Puyallup	20	80	100	151	301	602
Nisqually, Deschutes	17	40	57	69	110	160
Hood Canal Streams	9	42	51	68	100	158
Dungeness-Elwah	9	19	28	38	54	80
Streambank Erosion, All Basins	115		115	170	260	400
Tributary Areas	7,833	989	8,822	11,942	18,538	29,134
Total	10,908	4,821	16,059	22,668	37,153	64,066

^{1/} In \$1,000 (1968).

^{2/} Including \$5,000 on Sammamish and \$325,000 on Green-Duwamish for which no breakdown is available.

In estimating the level of future nonagricultural damages, consideration was given to growth in damageable buildings and equipment, transportation facilities, utilities, flood protective works, parks, and fish hatcheries, and in flood relief expenditures and employee and business losses. Estimates of residential damage considered future population and per capita income growth and the pattern of consumption expenditures. For commercial buildings and equipment, the rate of growth was based upon projected total consumer purchasing power within the service area of the commercial developments. Projected industrial output and acreage requirements for industrial use in each flood plain provided the basis for estimating growth of industrial buildings and equipment.

The growth in transportation facilities was based upon population growth rates. Future flood damage to public utilities was expected to increase at a rate similar to trends in power, water, gas, and telephone use. The future need for increased park facilities and fish hatcheries was based on local and regional population growth. Flood relief expenditures are expected to follow retail price indexes and population growth trends. The growth in employee and business losses was based on employment and wage trends and volume of retail and wholesale inventories and sales.

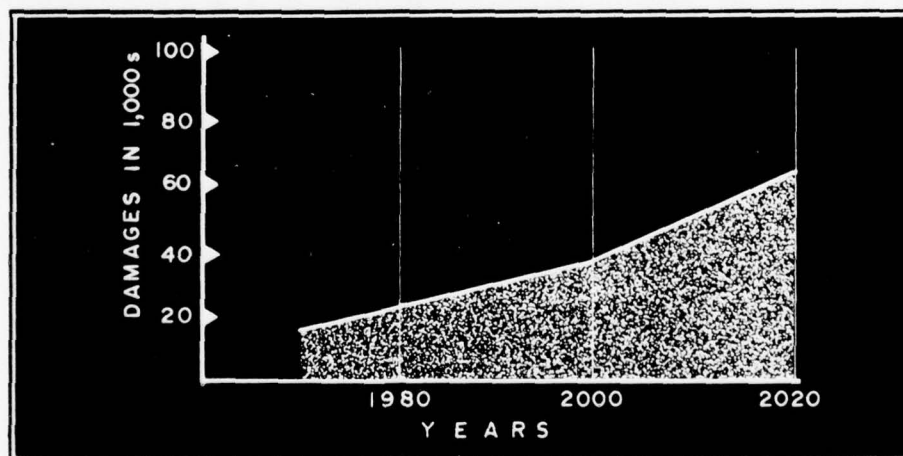


Figure 29. Projected Average Annual Flood Damages, Subregion 11.

Streambank Erosion

The annual loss of land due to streambank erosion is not expected to change except as influenced by corrective measures. The value of land loss and other damages, however, will increase in proportion to the value of lands. Sedimentation damages, being primarily based on removal costs, will remain constant.

Future average annual sedimentation damages are estimated to amount to \$170,000 in 1980, \$260,000 in 2000, and \$400,000 in 2020.

MEASURES REQUIRED TO SATISFY NEEDS

Measures to alleviate flood damages in most of the problem areas in the subregion are detailed in Appendix XII, Flood Control, and Appendix XVI, Plan Formulation, PSAW. (1) Those appendixes presented a flood control plan that would provide 100-year or better protection for all urban areas and areas needed for urban expansion and 50- or 25-year protection for rural areas. A need was recognized for flood plain zoning regulations to control types of development and to specify flood proofing measures. Such regulations were specified for all areas with less than 100-year protection and to remain in effect until such 100-year protection is provided by structural means. Two options were presented for the Skagit, with and without the Lower Sauk River Storage project, and the Nisqually, with and without navigation development on the delta. Total costs for flood control structural measures would range from \$326.6 to \$379.6 million, depending on which of the above options are selected.

Storage

Approximately 2.2 million acre-feet of flood control storage would be required to contain floods of 100-year frequency to nondamaging stages considering present-day stream channel capacities and existing levees. These needs are in addition to the existing storage allocated to flood control and the power storage used incidentally for flood control. They do not include storage needs on several of the streams flowing into Hood Canal where damages occur in small isolated areas and the lack of economic justification is obvious. Known storage needs and sites where some data are available are shown in table 111.

Basically, the flood control storage plan for Subregion 11 comprises 1,191,000 acre-feet of storage for flood control in addition to the 332,000 acre-feet plus incidental storage presently available. Storage in new reservoirs would amount to 871,500 acre-feet, increased capacity in three existing reservoirs would provide 165,000 acre-feet, and 155,000 acre-feet would be made available through joint-use of existing space. If developed for flood control alone, the total estimated cost would be \$540.4 million for new construction. In plan formulation of the PSAW study, several of the less favorable projects were dropped and two proposals for flood control storage were prepared. One

Table 111 - Needed and Proposed Flood Control Storage,
Subregion 11

Basin and proposed storage site	Needed storage (ac.ft.)	Effective storage (ac.ft.)	Estimated development cost based on January 1968 prices
Nooksack-Sumas	210,000		
Edfro <u>3/</u>		63,000 <u>3/</u>	\$ 27,200,000
North Fork <u>3/</u>		21,000 <u>3/</u>	21,400,000
Skagit-Samish	800,000		
Upper Baker <u>3/</u>		100,000 <u>3/</u>	1/
Lower Sauk <u>3/</u>		134,000 <u>3/</u>	61,200,000
Stillaguamish	150,000		
Robe		70,000	21,200,000
Oso		80,000	25,100,000
Snohomish	700,000		
N.F. Snoqualmie <u>3/</u>		50,000 <u>3/</u>	29,200,000
M.F. Snoqualmie <u>3/</u>		120,000 <u>3/</u>	40,700,000
Sultan River <u>3/</u>		100,000 <u>3/</u>	13,400,000 <u>2/</u>
N.F. Skykomish		140,000	129,400,000
Miller River		45,000	47,900,000
Beckler River		70,000	43,900,000
S.F. Tolt River <u>3/</u>		15,000 <u>3/</u>	2,000,000 <u>2/</u>
Pilchuck		15,000	15,700,000
Sammamish	6,000		
Lake Sammamish		6,000	1,000,000
Cedar	60,000		
Chester Moose Lake <u>3/</u>		50,000 <u>3/</u>	5,600,000 <u>2/</u>
Taylor Creek		10,000	10,200,000
Puyallup	55,000		
Orting <u>3/</u>		24,000 <u>3/</u>	26,500,000
S. Prairie Cr.		8,500	15,300,000
Nisqually-Deschutes	70,000		
Alder		55,000 <u>3/</u>	1/
Shellrock Ridge <u>3/</u>		15,000 <u>3/</u>	3,500,000
Skokomish	60,000		
Elwha-Dungeness	65,000		
Farm Ponds and Reservoirs		13,800	
Totals	2,176,000	1,205,300	\$540,400,000

1/ Project operation would be changed to include flood control storage.
Reimbursement for power losses would be required.

2/ Existing project would require modification to provide storage for
flood control.

3/ Retained in PSAW plan formulation.

proposal would retain the Lower Sauk River project in the Skagit Basin, the other would not. Storage costs allocated to flood control would be \$183,103,000 or \$125,103,000, depending on whether the Sauk River storage was included. Storage plans for the several basins are discussed in the following paragraphs.

Nooksack-Sumas

In the Nooksack-Sumas Basin, nearly all of the 210,000 acre-feet of storage needed for control of flooding could be developed by a dam near Deming below the confluence of the North and South Forks. However, such a project would inundate part of the flood plain lands for which protection is needed and is not considered practicable. The proposed projects on the North Fork and at the Edfro site on the South Fork would enable levees on the lower reaches to substantially eliminate further flooding. Upstream storage is not appropriate in the Sumas subbasin, but elimination of overflow from the Nooksack would make other flood control measures feasible.

Skagit-Samish

Approximately 800,000 acre-feet of additional flood control storage would be required to control 100-year floods on the Skagit River. Sites for such storage exist on the main Skagit, Baker, Sauk, Suiattle, and Cascade Rivers. The most feasible plan would be to utilize the 100,000 acre-feet prescribed in the license for Baker Dam and to construct a 134,000 acre-foot reservoir on the lower Sauk River. No storage was considered on the Samish River but overflow from the Skagit would be eliminated. The PSAW plan formulation presented two alternatives, one with storage on the Sauk River, and one without but with a more extensive, higher levee system to attain the same degree of protection.

Stillaguamish River

Storage is not presently a feasible means of flood control on the Stillaguamish. If the channel and levee work that is immediately needed and proposed in the PSAW study is accomplished, the remaining needs for storage would amount to 150,000 acre-feet. Potential sites exist on both the North and South Forks. The two most promising are Robe on the South Fork and Oso on the North. These two sites, together, could develop the needed 150,000 acre-feet of effective flood control storage.

Snohomish River

Approximately 700,000 acre-feet of flood control storage would be required to provide a 100-year level of control in the Snohomish Basin. There are not enough good storage sites to develop this amount, but eight reservoirs with an aggregate capacity of 555,000 acre-feet would control 40 to 45 percent of the basin runoff. PSAW plan formulation retained four reservoirs with a total storage of 285,000 acre-feet.

Cedar-Green

Data are not available to determine the total storage needs of the Sammamish, Cedar, or Green Rivers. However, studies show that it is possible to construct a small dam to control the outflow from Sammamish Lake and secure 6,000 acre-feet of storage, raise the dam at the outlet to Chester Morse Lake on the Cedar to provide 50,000 acre-feet of flood control storage, and construct a dam on Taylor Creek to provide 10,000 acre-feet. No further storage is considered for the Green River.

Puyallup-White

Approximately 55,000 acre-feet of storage would be needed to control flooding on the Puyallup and Carbon Rivers above the confluence with the White River at Puyallup. Partial protection could be provided by 24,000 acre-feet of storage on the Puyallup at a site about 5 miles above Orting and 8,500 acre-feet on South Prairie Creek above its confluence with Carbon River. No storage is needed on the White River beyond that provided by the existing Mud Mountain Dam.

Nisqually-Deschutes

Storage to reduce damages by Nisqually River in Mt. Rainier National Park above Alder Reservoir is not practicable. Below Alder Reservoir, 55,000 acre-feet that could be developed through joint use of power storage would substantially eliminate flood damages. In the Deschutes Basin, an estimated 15,000 acre-feet at the Shellrock Ridge Site would control floods up to 100-year frequency.

Skokomish River

An estimated 60,000 acre-feet of flood control storage, which could be developed at a site on the South Fork, and 42,000 acre-feet in the existing Cushman Reservoir on the North Fork, would control floods up to 100-year frequency. The PSAW plan (1) does not include development of new flood control storage but recommends that continued incidental use be made of power storage in Cushman Reservoirs.

Elwha-Dungeness

In the Elwha and Dungeness Basins, a total of 65,000 acre-feet of storage would be needed to control floods to nondamaging stages. On the Dungeness River, an estimated 15,000 acre-feet of storage, which could be provided at a site near river mile 15, would control floods up to 100-year frequency. On the Elwha, 8,000 acre-feet of storage above the spillway crest of the existing Lake Mills Reservoir would be suitable for flood control, but would be inadequate to meet the needs. The PSAW study does not include flood control storage, but recommends continued incidental use of power storage in Lake Mills.

Levees and Channel Improvements

In addition to storage, both levees and channel improvements are required to provide protection to the populous Puget Sound area. Protection to the urban and nonurban areas, as well as to transportation and other developments, requires construction of 148.4 miles of levees and 52.5 miles of channel improvements at a total cost of about \$200 million. Details by basin are shown in table 112.

Nooksack-Sumas Rivers

Major levee construction could be used to protect urban areas extending into the flood plain at Marietta, Ferndale, Everson, Nooksack, and Sumas and to control floods in major agricultural areas along both banks of the Nooksack River. The plan provides for a levee 6 miles long on the right bank below Ferndale at an estimated cost of \$2,500,000; a levee 7 miles long on the right bank from Lynden to above Everson at an estimated cost of \$3,500,000; a levee 10 miles long on the left bank opposite Lynden at an estimated cost of \$5,000,000; and a levee at the town of Sumas at an estimated cost of \$1,500,000.

Table 112 - Proposed Levees and Channel Improvements ^{1/},
Subregion 11

<u>Basin</u>	<u>Levees Total Length (miles)</u>	<u>Channel ^{2/} Improvements Total Length (miles)</u>	<u>Cost</u>
Nooksack-Sumas	26	0	\$ 12,500,000
Skagit-Samish	46.5	10.8	43,600,000 ^{3/}
Stillaguamish	24.0	6.2	11,400,000
Snohomish	13.0	18.5	106,750,000
Cedar-Green	13	16	13,300,000
Puyallup	8	0	2,600,000
Nisqually-Deschutes	2 ^{4/}	1 ^{4/}	3,000,000 ^{4/}
Hood Canal Streams	6.4	0	1,290,000
Elwha-Dungeness	9.5	0	2,750,000
Small Tributaries	147	1,048	
Total	295.4	1,100.5	\$197,190,000

^{1/} From PSAW comprehensive water resource study.

^{2/} Includes levee setback to obtain greater hydraulic capacity.

^{3/} With storage on Sauk River, without storage cost would be \$51.6 million.

^{4/} Not required unless navigation is developed on the Nisqually site.

Skagit River

Major raising of the levee system along the Skagit River and its distributaries in the delta area is not practical. The higher water levels resulting from the levee raising would increase the flood problems upstream and could cause levee foundation failures. The most practical answer is moderate raising of low areas in the existing delta levee system together with widening of constricted channel reaches and construction of a bypass channel, known as the Avon Bypass, into Padilla Bay. About 5.5 miles of levee to protect 6,000 acres in the Nookachamps Creek area and about 7 miles of levees in two locations to protect the towns of Hamilton and Sedro Woolley are also required.

Stillaguamish River

Levee and channel improvements will protect Stanwood and the flood plain upstream to Silvana and levees only from Silvana to Arlington at a total cost of \$11.4 million.

Snohomish River

Levees and major channel improvements are proposed on the lower 10 miles of river and the existing levees from mile 10 to mile 18.5 would be set farther back from the river to provide greater flood capacity. Levees would be constructed to protect the towns of Carnation, Gold Bar, Snohomish, Sultan, Monroe, and Skykomish. Total cost for all levee and channel work would be \$106.75 million.

Cedar, Sammamish, and Green Rivers

The 800-acre flood plain of the Cedar River is scattered along the lower 20-mile reach and has a maximum width of about one-half mile. The Sammamish Valley is protected from spring floods up to about a 40-year frequency and winter floods up to about 5-year. Damages in the 3,600-acre flood plain are generally limited to minor inundation of agricultural lands; therefore, no additional levees or channel improvements in either of these basins are proposed. In the Green River Basin, additional channel capacity would be provided below Auburn to accommodate the maximum authorized regulated flow of 12,000 cfs at Auburn, plus any additional river flow added by interior drainage pumped into the river. The total cost of \$13 million is based on increasing the height of existing banks and dikes.

Puyallup River

In the Puyallup River Basin, the plan proposes a levee and associated channel work to protect the town of Orting from flooding by the Puyallup and Carbon Rivers and a levee to protect the town of South Prairie from South Prairie Creek. Total cost would be \$2.6 million.

Nisqually-Deschutes Rivers

No levees or channel work are proposed in the Nisqually or Deschutes Basins unless a port and industrial complex is constructed at the mouth of the Nisqually. If such a complex is constructed, flood protection can be provided by levees, fill, and channel construction. Although costs would be dependent on the location and extent of development to be protected, they are not expected to exceed \$3 million.

Hood Canal Streams

Proposals include a levee to protect Dosewallips State Park, about 5 miles of levees along the lower 10 miles of the Skokomish River, and 1.1 miles of levee along the lower Big Quilcene. Total cost would be \$1.29 million.

Elwha-Dungeness Rivers

Approximately 8 miles of levee along the left bank of the Dungeness River would protect 2,200 acres. The levee would require revetment protection and expensive maintenance because of the large amount of debris and bed load carried by the river during floods. Another 1.5 miles of levee along the Elwha would protect the 750-acre flood plain near the mouth. Total cost of both projects would be \$2.75 million.

Flood Plain Regulation

The Puget Sound area must rely heavily on zoning regulations to minimize future development in the flood plain that would be subject to flood damages. Regulations in each area must be tailored to the risk of flooding and the type and degree of structural protection provided. Even areas that have relatively complete protection should be regulated and the public should be reminded periodically that some risk remains. Basically, flood plain regulations are considered a local responsibility but the PSAW study recommends a change in the existing State legislation, Chapter 86.16 RCW (Revised Code of Washington), an act relating to flood control, to enable the State to override local governments if necessary. Salient features of the recommended revision to the code include:

- a. Preemption of State jurisdiction of the flood plains of all rivers, creeks, lakes, and coastal areas.
- b. Explicit definition of minimum requirements of flood plan regulations to be adopted by local governments and of time limitations for this accomplishment. The regulations should apply to subdivision regulations, zoning ordinances, and building codes.
- c. Retention of state authority to invoke proper land-use regulations in absence of appropriate local action.
- d. Provision for enforcement of adopted regulations, declaration of certain acts to be unlawful, and prescription of appropriate penalties.

Cost of the program is estimated to be \$2.8 million for State and local administration over the full 50-year period to 2020. No estimate was made of the cost of complying with the regulations or of the value of any possible development that might be foregone.

Streambank Erosion

Treatment is possible through either structural or vegetative means. The use of vegetative protective measures would be confined to smaller streams and headwaters. The average cost of vegetative protection is estimated at \$8,000 per mile. Structural protective measures would be predominantly riprap, having an estimated cost of \$40,000 per mile. An estimated 75 percent of seriously eroding streambank will require treatment prior to 2020 at a total cost of about \$1,600,000.

Watershed Protection and Minor Tributary Areas

The Puget Sound Study considered watershed protection and minor tributary needs with land measures. That plan for these matters is not shown. In preparing Columbia-North Pacific Appendix VIII, Land Measures and Watershed Protection, the following needs were developed.

A combination of improved management practices, land treatment measures, and water control structures will be necessary to satisfy future watershed needs for flood prevention. The most effective cropland practices that are still needed are 139,000 acres of conservation cropping systems, 56,000 acres of crop residue use, and 367 miles of drainage conduits or ditches. Forest land treatment measures required to reduce sediment and tributary floodflows include 55,100 acres of erosion control treatment and 1,110 miles of road and trail restoration.

Structural measures that will be needed comprise 3,600 ponds and small reservoirs with an aggregate capacity of 14,000 acre-feet, 150 miles of levees, 1,050 miles of stream channel improvements including 20 miles of stabilization, and 700 miles of streambank protection.

Comprehensive treatment comprising land measures and flood control structures on small streams will be needed on 110 watersheds prior to 2020. These watersheds have 545,300 acres subject to flooding.

Additional details on watershed protection and flood control structures on minor streams are included in Appendix VIII.

Summary of Flood Control Measures

Relatively complete control of flooding in most areas of Subregion 11 could be attained by constructing reservoirs at appropriate locations with an aggregate capacity of more than 2.2 million acre-feet. The PSAW study recommended two alternative plans for storage. One would comprise 12 reservoirs with an aggregate capacity of 747,000 acre-feet usable for flood control at an allocated cost of \$183,103,000. The other would comprise 11 reservoirs with a capacity of 613,000 acre-feet at an allocated cost of \$125,103,000. The storage would be supplemented by nearly 150 miles of levees and more than 50 miles of channel improvements. Costs would range from \$194,190,000 to \$205,190,000 depending on whether the Sauk River Reservoir in the Skagit Basin was included and whether a navigation-industrial complex were constructed on the Nisqually Delta. Flood plain zoning regulations would be needed in all flood susceptible areas to insure against inappropriate development. Total costs for flood control structural measures by time periods are shown in table 113.

Table 113 - Flood Control Structural Costs,
Subregion 11

	W/O Sauk R. Storage or Nisqually Delta Development	W/Sauk R. Storage but w/o Nisqually Delta develop.	W/O Sauk R. Storage with Nisqually Delta Development	W/Sauk R. Storage & Nisqually Delta Develop.
through 1980	\$175,243,000	\$167,243,000	\$175,243,000	\$167,243,000
1980-2000	107,170,000	165,170,000	110,170,000	168,170,000
2000-2020	44,205,000	44,205,000	44,205,000	44,205,000
Total	\$326,618,000	\$376,618,000	\$329,618,000	\$379,618,000



SCARCE-02

12

SUBREGION 12

OREGON CLOSED BASINS

GENERAL

Subregion 12 includes nearly all the portion of the Great Basin within the State of Oregon. It consists of several landlocked high plateau drainage basins in south central Oregon including most of Harney and Lake Counties. The Lost River drainage, excess waters of which have been diverted into Klamath River, and Goose Lake Basin are not included in the Columbia-North Pacific Study.

Location and Extent

The subregion has an area of approximately 17,904 square miles. It is bounded by the Owyhee and Malheur drainages on the east, the John Day and Deschutes Basins on the north and west, the Klamath and Goose Lake Basins on the west and southwest, and the states of California and Nevada on the south.

Topography

The area along much of the perimeter is rough and mountainous. The basin floors are, for the most part, arid plateaus which exceed 4,000 feet in elevation, and the mountain ranges separating the basins and around the subregion average from 1,000 to 5,000 feet higher. Miocene to recent lava flows characterize the higher elevations while the basin floors are covered with alluvium deposited during the pleistocene glacial period when much of the subregion was covered by large lakes. Much of the subregion interior floor is a series of tilted fault blocks with scarps generally trending north-south. Abert Rim, which rises nearly 2,500 feet above the east shore of Lake Abert, is one of the largest and most definitely exposed geological fault scarps in North America. Drainage is to several grabens, most of which contain large, shallow lakes, interspersed throughout the basin. Inflow to these lakes is offset by evaporation and, in the case of Silver Lake, by seepage loss. The annual changes in lake levels represent the current hydrologic surpluses or deficits for the basin. Much of the water in the subregion is alkaline, but the waters in the streams and most of the cold wells and springs are sufficiently pure for domestic and agricultural use.

Several hot springs and hot artesian wells are highly alkaline. The alkalinity of the water in the lakes ranges from as low as 135 ppm in Crump Lake to as high as 80,000 ppm in Lake Abert during dry cycles. Generally, the lakes which overflow contain less than 500 ppm alkalinity and those which do not overflow, more than 2,000 ppm.

Climate

The climate is semi-arid, characterized by cold winters and hot, dry summers, with intermittent thundershowers. Annual precipitation, which ranges from a minimum of 10 inches on the basin floors to a maximum of about 40 inches on the forested headwaters, occurs mostly during the winter. Long periods of dry weather are not uncommon on the basin floor and may be experienced any time from late spring to early winter. Most of the winter precipitation above 6,100 feet, the mean elevation of the subregion, falls as snow, which accumulates from November to March and melts each spring to produce an annual high-water period. Annual snowfall averages about 2 feet across the basin floors on the western side of the subregion increasing easterly to 4 feet near Burns and up to 8 or more feet in the higher elevations. Oregon Closed Basins is separated from the moderating influences of the Pacific Ocean by the intervening Coast and Cascade Ranges and experiences a wide range of temperatures. Recorded extremes are 103°F. at Paisley and -54°F. at Seneca. At Burns the January average temperature is 24°F., and the July average is 70°F. Percentage of possible sunshine is very high during July and August, the driest months, decreasing to comparatively low values during winter.

Economic Development

The economy is based on livestock and logging. Agricultural development is restricted by the lack of precipitation, harsh climate, short growing season, and unsuitable soils in most areas. Large tracts are so arid that they remain undeveloped and uninhabited. The sparse vegetation does not make an ideal range and ranches must be large to provide adequate income for the owner. Lands adaptable to agriculture and industrial development include the areas along perennial streams and the marshlands adjacent to lakes and creeks. The growing season averages about 90 days and killing frosts may occur at any time, so only fast-growing, frost-resistant crops can be raised. Improved irrigation and drainage practices around Burns and Paisley have made the production of better grasses and legumes possible and expanded the acreage available for alfalfa and barley. Only

a minor amount of storage has been developed; therefore, the acreage actually irrigated in any year varies with the runoff. Forests on the north and west of the subregion provide timber for the mills located in Hines, Burns, and Paisley. The largest plant, which cuts about 130 million board feet annually, is at Hines. The only incorporated cities in the subregion are Burns, Hines, and Paisley, with 1966 populations of 4,150, 1,390, and 300, respectively. Other settlements consist of unincorporated towns, crossroad trading centers, and ranches. The total population (1965) is 13,300. U. S. Highways 20 and 395 cross the basin east and west, and north and south, respectively. State Highways 31 and 140 serve the west and south sides of the basin, and State Highways 78 and 205 serve the areas south and east of Burns. A network of county roads connects the farm and ranch units with the Federal and State systems. Rail facilities are confined to Silvies River Basin. Numerous airstrips are found in the subregion, primarily for itinerant or local ranchers use. Scheduled air service is available triweekly at both Burns and Lakeview.

Streams

Practically all runoff comes from the mountain areas. The principal streams include the Chewaucan, Silvies, and Donner Und Blitzen Rivers; and Silver, Deep, and Honey Creeks.

Chewaucan River

The headwaters of Chewaucan River are located above 7,000 feet elevation in the mountains of Lake County along the southwestern edge of the subregion. The drainage area above Paisley contains 275 square miles and lies mostly within the Fremont National Forest. Below Paisley, the Chewaucan River flows through Chewaucan Marsh to Lake Abert. The marsh is about 20 miles long and 3 to 6 miles wide. Nearly all of the irrigable land in the basin is in Chewaucan Marsh.

Silvies River

Silvies River is a perennial stream in its upper reaches. Its headwaters are in the northeast corner of the subregion in the Malheur National Forest. It flows generally southerly from the vicinity of Seneca to Burns and thence southeasterly to Malheur Lake. A few miles above Burns, Silvies River breaks out of a mountainous canyon into an alluvial valley and below Burns the stream separates into the East and West Forks and a maze of canals and distributaries. In years of high runoff the stream

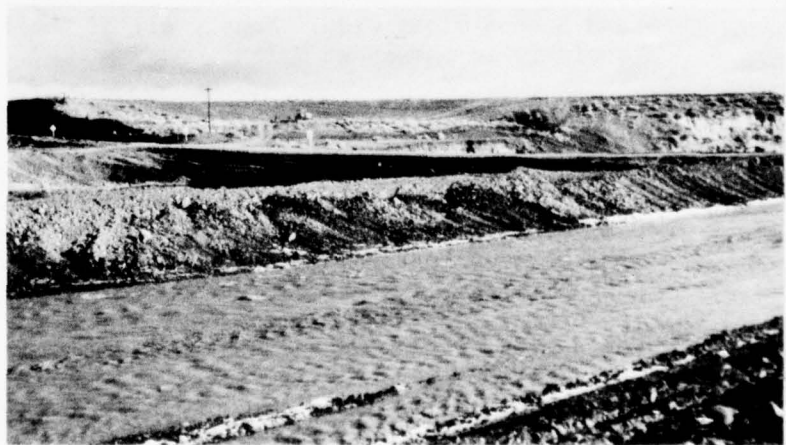
ultimately empties into Malheur Lake, which overflows into Harney Lake during wet periods. Between Burns and the lake, Silvies River traverses a nearly level alluvial delta and falls about 2 feet per mile. The two principal tributaries are Bear and Emigrant Creeks. Bear Creek joins the river from the east at Seneca and Emigrant Creek connects from the west about 19 miles northwest of Burns. The drainage area above the gaging station about 11 miles northwest of Burns is 934 square miles.

Donner Und Blitzen River

Donner Und Blitzen River is a spring-fed perennial stream in its upper reaches, draining the unforested west slope of Steens Mountain. The river flows northerly about 50 miles and enters Malheur Lake from the south. A drainage area of 200 square miles, covered only with desert vegetation, extends upstream from the gaging station located near Frenchglen. Much of the flow downstream from Frenchglen is used for irrigation and operation of a large migratory waterfowl refuge.

Silver Creek

Silver Creek rises in the Ochoco National Forest near the Northwest corner of Harney County. The stream flows generally southeasterly about 45 miles before it empties into Harney Lake. The drainage area above the gaging station, located 14 miles northwest of Riley, is 228 square miles.



Deep Creek

Deep Creek originates in Fremont National Forest on the eastern slope of Crane Mountain a few miles southeast of Lakeview. The stream flows northeasterly a distance of about 20 miles through a deep canyon to Adel in Warner Valley and thence about a mile easterly to its confluence with Twentymile Creek. Below the confluence the waters spread out over the meadows and marshland and eventually drain into Crump Lake. A gaging station located 5 miles west of Adel records the flow of the 249-square mile drainage area.

Honey Creek

Honey Creek drains the plateau northwest of Drake Peak and flows easterly into Hart Lake after entering Warner Valley at Plush. A drainage area of 170 square miles extends upstream from the gaging station located near Plush. Some of the marshes and lakes in Warner Valley are diked, and the water levels are controlled.

HISTORY OF FLOODING

Annual high water usually occurs in the March-April flood season. However, some of the largest floods of record have occurred during the winter season as a result of intense rainstorms. Freshets damage buildings, fences, irrigation ditches, levees, and roads, and occasionally destroy haystacks used as winter feed stations for the cattle. Winter flooding around

Channel of the Chewaucan River at Paisley reopened after flood; January 1965. (USCE)



Paisley is frequently aggravated by ice jams. In this semi-arid subregion, the significant flood streams are Chewaucan and Silvies Rivers. The largest floods known are shown on table 114.

Table 114 - Known Major Floods, Subregion 12

<u>Date</u>	<u>Stream</u>	<u>Discharge</u> (Cfs)	<u>Damages</u> (\$1,000)
1897	Silvies R.	9,000	1/
Apr 1904	Silvies R.	4,730	1/
Nov 1909	Chewaucan R.	4,000	1/
Apr 1943	Silvies R.	3,830	258
Apr 1952	Silvies R.	4,960	569
Feb 1963	Chewaucan R.	3,100	1/
Dec 1964	Chewaucan R.	6,490	2,342
Dec 1964	Silvies R.	3,130	1,361
Dec 1964	Silver Cr.	1,810	74
Dec 1964	Donner Und Blitzen	2,690	10
Dec 1964	Honey Cr.	11,000	62
Dec 1964	Deep Cr.	9,420	520 2/

1/ Not available.

2/ Includes damages on Twentymile Cr.

PRESENT STATUS

Existing Measures

Flood Forecasting

Flood warnings are issued by the Portland River District Office of the National Weather Service for the station at Burns on Silvies River. A flood stage has not been determined (Dec. 68).

Flood Control Storage

There is no flood control storage in the Oregon Closed Basins. Approximately 2,300 small reservoirs and farm ponds with a total capacity of 155,300 acre-feet are essentially for irrigation and livestock drinking water and are filled each season at the earliest opportunity to retain as much runoff as possible for irrigation during the dry months. This filling usually catches the annual freshet but not all floodwaters during seasons with winter floods or exceptionally heavy spring runoff. During the annual spring runoff on Silvies and Chewaucan Rivers, floodwaters are diverted from the streams and spread over the fields as a form of irrigation. In this manner, minor to moderate floods are

put to beneficial use. Major floods, however, and winter floods such as that of December 1964, destroy the diversion works and damage croplands, fences, and roads.

Levees and Channels

Prior to World War I local interests dredged the Chewaucan River through Chewaucan Marsh between Paisley and Lake Abert, a distance of about 20 miles, and constructed levees across the low areas with the material. In 1937, they cleaned out the channel again and used the material to reinforce the adjoining levees. These works and nearby highway facilities were damaged during the flood of December 1964. All major damage was repaired following the flood.

Local interests constructed a low levee along the right bank of the Silvies River between the highway bridges at Burns, which provides partial protection for the town. Other local improvements consist of channel rectification along a short reach of the East Fork and along two sections of the West Fork, and the construction of several levees along the West Fork to trap water for irrigation purposes.

Levees have been constructed in other areas to reclaim swampy lands around several of the large lakes. These levees, however, do not protect against flooding and are not considered herein.

Watershed Protection

More than 103,000 acres of cropland have had effective combinations of practices which reduce erosion and sedimentation and assist in the reduction of floods. The practices which are most effective include conservation cropping systems on 19,000 acres, crop residue use on 16,000 acres, land shaping on 41,000 acres, and 25 miles of diversions and terraces.

Forest land treatment measures to reduce sediment and localized floodflows include 1,500 acres of erosion control by seeding and gully stabilization and 700 miles of road and trail restoration.

Rangeland practices of particular significance in reduction of erosion and sediment and aiding in reduced flow include 169,800 acres of grass seeding and 298,300 acres of brush control. Excessive grazing was reduced on 4.1 million acres.

It is estimated that the soils of Subregion 12 have a water holding capacity of at least 4,412,000 acre-feet, or an average of 4.65 inches over the entire watershed. With proper land treatment and under ideal climatic conditions this storage would be useful in controlling or retarding runoff. Additional information on land treatment is included in Appendix VIII.

Flood Plain Zoning

The Oregon State Water Resources Board has issued a report showing the extent of flooding by a number of small, normally-dry, washes in the hills northwest of Burns and Hines. The areas flooded include residential developments adjacent to both towns and undeveloped areas close by. No other flood plain studies have been made and no zoning regulations have been adopted.

PROJECTIONS AND NEEDS

Economic Trend

Population is expected to grow at a slower rate than in other parts of the region, due to the arid to semi-arid character of this subregion. In 1965, the population was 13,300 a density of about one person per square mile. Population projections are for 16,300 in 1980, 18,700 in 2000, and 21,300 by 2020, equivalent to a growth rate of 0.9 percent per year. Most of this growth is expected to take place in the Burns-Hines area in Silvies River Basin.

Rapid growth of the economy, which is based on livestock and timber, is precluded by the lack of water, but a slow increase in agricultural production is expected to occur. However, employment in agriculture is expected to remain about at its present level. The increase in total employment to support the projected growth of population would come in industries associated with recreation and services and in fabrication of wood products.

The major flood plains are on the Chewaucan River, Silver Creek, and Silvies River, and in Warner Valley. There are more than 151,000 acres of agricultural land in the flood plains, exclusive of the acreage in the Malheur National Wildlife Refuge in Donner Und Blitzen and Silvies River Basins. Sixty-four percent of the flood plain land is in pasture and hay; 15 percent in field, truck, and special crops; and the remaining 21 percent in farmstead plots, brush, and waste areas. About 110 acres of urban land in Burns and Paisley are exposed to flooding. As pressures for use of the flood plain lands increase, a rise in

damage potential is predicted and the demand for flood control projects may become more urgent.

Future Flood Damages

The streams with the highest demand potential are the Chewaucan and Silvies Rivers. Damages caused by a major flood may exceed \$4 million under present development conditions. In projecting present flood damages to arrive at estimates for potential future damages, two categories have been considered:

(1) Rural damages, which are expected to remain the highest of the damage categories in many areas, are expected to increase at two percent per year from increasing capital investment and agricultural productivity per acre.

(2) Urban damages (transportation, industrial, commercial, and urban residential) are projected to increase as a function of total personal income, which determines the level of investment in these categories. It is estimated that total personal income will increase at an average rate of about 3.8 percent annually with a slightly greater increase during the early part of the forecast period.

Table 115 - Distribution of Average Annual Flood Damages, Subregion 12

	With 1967 Economic Development			With Projected Economic Development		
	Rural	Urban	Total	1980	2000	2020
	(\$1,000 - 1967 Price Levels)					
Chewaucan River	132	196	328	491	921	1,510
Silvies River	172	18	190	248	384	604
Silver Creek	9	2	11	14	24	39
Warner Valley	43	37	80	115	208	372
Riverbank Erosion	50	9	59	59	61	63
Tributary Areas	785	16	801	1,057	1,570	2,331
Closed basins, total	1,191	278	1,469	1,984	3,168	4,919

Summary of Flood-Control Needs

Present (1967) average annual flood damages in the Closed Basins as a whole, which total \$609,000, are comprised of 58 percent rural damages and 42 percent urban. Rural damages include principally the loss of hay and feed, the loss of topsoil, damages due to depositing of alkali on the fields, and the costs of moving cattle to higher ground and feeding when local stocks of hay and feed are destroyed. Urban damages include washed-out roads, damaged bridges, and the costs attendant upon traffic

interruption. While rural damages are at present larger than all other damages combined, the greater rate of growth expected in the urban category means that this latter class of damages will exceed agricultural damages by the year 2000. There is no serious streambank erosion in the subregion, but approximately 10 percent of the 9,800 miles of stream channels have moderate erosion. Total damages due to streambank erosion are estimated to be \$59,000.

Average annual damages in small tributary areas amounting to \$801,000 result from flooding of 183,500 acres. The lands subject to flooding comprise 119,000 acres of cropland, 64,000 acres of range and pastureland, and 500 acres of urban development.

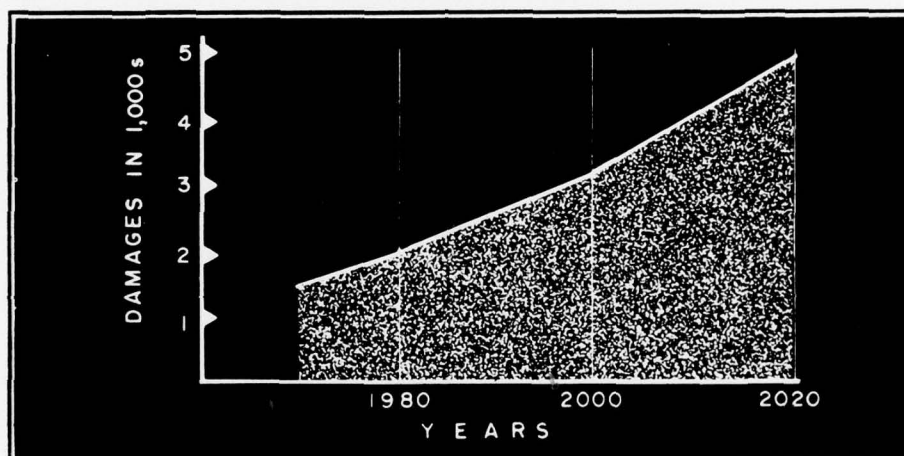


Figure 31. Projected Average Annual Flood Damages, Subregion 12.

MEASURES REQUIRED TO SATISFY NEEDS

Storage

The only known potential in the subregion for development of flood control storage exists in the Chewaucan and Silvies River Basins. Two potential reservoir sites in those basins are expected to be utilized within the next few years. Coffeepot project on Chewaucan River has a primary function to provide storage to irrigate land within the Chewaucan Irrigation District boundaries. A secondary function is to provide flood control benefits at Paisley. Local interests are expected to begin construction when financing can be arranged.

A Corps of Engineers study to include consideration of multiple-purpose storage and other water-resource development

needs and potentials in the Silvies River Basin is underway and scheduled for completion in 1973. The study will identify existing and future needs and develop a plan for the optimum use of water and related resources of that basin. A reservoir on Silvies River could function for both flood control and water conservation. To control river stages during flood conditions to comparatively non-damaging stages, upstream storage of about 180,000 acre-feet would be required. Because of the relation of Silvies River floodflows to the operation and use of the Malheur National Wildlife Refuge, careful and closely coordinated planning will be required if storage control of floods is to be realized.

Levees

Several areas along the Chewaucan and Silvies Rivers have existing levee protection against low frequent floods. If the dams discussed above are constructed, existing levees may protect against 50- to 100-year frequency flows. The remaining damage areas do not appear to warrant extensive levee protection prior to approximately 2020.

Channel Improvement

The study of the Silvies River Basin, as mentioned above, will include consideration of a plan for channel improvement extending from the vicinity of Burns downstream to the vicinity of Malheur Lake. This project may be feasible by 1980.

Flood damages along Chewaucan River could be reduced by channel improvements between Gravelly Ford and Lake Abert. However, flood-control storage at the Coffeepot site would probably reduce flood stages to such a degree that channel work would not be required, at least in the near future.

Zoning, Forecasting, and Emergency Operations

Future urban development in the vicinity of Burns, Hines, and Paisley might spread into flood-prone areas if land-use plans are not developed at an early date. Thus, adoption of zoning ordinances by local governments would assist in reducing future flood damages. Provision of flood plain information and flood plain management assistance would stimulate local awareness of the need to zone and might lead to development of land-use plans. Sufficient amounts of flood-free lands appear to be available in the Burns, Hines, and Paisely areas, so that economic

losses would not occur if urban development of flood plain land were prevented by zoning.

Reliable flood forecasting, particularly of winter floods, is difficult for the Burns-Hines and Paisley areas, since the river basins affecting those areas are small and little lead time is available after flood-causing conditions develop. The potential for spring flooding can be assessed by measurement of the snow-pack before the start of the normal spring runoff season.

Land Treatment and Watershed Protection

Improved management practices, land treatment measures, and water control structures to satisfy future watershed needs are outlined in Appendix VIII, Land Measures and Watershed Protection. Practices pertinent to control of floodwaters include 10,000 acres of conservation cropping systems, 9,000 acres of crop residue use, 254,000 acres of irrigation water management, 75,000 acres of forest erosion control treatment, 185 miles of road and trail restoration, 883,000 acres of grass seeding, 643,000 acres of brush control, and 600,000 acres of grazing control. Structural measures include 360 miles of levees, 390 miles of stream channel improvement, 12 miles of stream channel stabilization, 920 miles of streambank protection, and 25 miscellaneous stream structures.

Comprehensive treatment programs comprising land measures and small flood control structures should be applied to 16 watersheds which have a total of 132,500 acres subject to flood damages. The works on these watersheds are included in the subregion totals of small flood control structures and land treatment measures cited above.

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G L O S S A R Y

ACRE-FOOT - The volume, of water, soil, sediment, etc. required to cover 1 acre 1 foot in depth, or 43,560 cubic feet.

AVERAGE ANNUAL FLOOD DAMAGES - The weighted average of all flood damages that would be expected to occur yearly under specified economic conditions and development. Such damages are computed on the basis of the expectancy in any one year of the amounts of damage that would result from floods throughout the full range of potential magnitude.

CHANNEL - A natural or artificial water course with definite bed and banks to confine and conduct continuously or periodically flowing water.

DETENTION STRUCTURE (DAM) - A structure constructed for the temporary storage of floodflows where the opening for release is of a fixed capacity and not manually operated.

EROSION CONTROL - The application of necessary measures including artificial structures, vegetative manipulation, water control, or physical soil changes to minimize soil erosion.

FLOOD - A great flow along a watercourse or a flow causing inundation of lands not normally covered by water.

FLOOD CONTROL - The control of flood waters by the construction of flood storage reservoirs, floodwater retaining structures, channel improvements, levees, bypass channels, other engineering works, or vegetative changes.

FLOOD DAMAGES - Economic losses resulting from flooding.

FLOOD FORECASTING - Flood forecasts are primarily the responsibility of the National Weather Service, National Oceanic and Atmospheric Administration, and are used to predict flood stages and times and indicate areas subject to flooding.

FLOOD FREQUENCY - The average interval of time between floods equal to or greater than a specified discharge or stage. It is generally expressed in years.

FLOOD INSURANCE - A means of spreading the cost of flood losses. It enables interested persons to purchase insurance against loss resulting from floods.

FLOOD PLAIN - Land bordering a stream and which receives overbank flow or all lands subject to inundation. Also see FLOOD.

FLOOD PLAIN INFORMATION REPORTS - Reports prepared to provide local governmental agencies with basic technical data to assist in planning for wise use and development of their flood plains.

FLOOD PLAIN MANAGEMENT - Comprehensive flood damage prevention program which requires integration of all alternative measures (structural and nonstructural) in investigation of flood problems and planning for wise use of the flood plain.

FLOOD PLAIN REGULATION - A general term applied to the full range of codes, ordinances, and other regulations relating to the use of land, water, and construction within a channel or flood plain area.

FLOOD PROOFING - A combination of structural changes and adjustments to properties subject to flooding primarily for the reduction of flood damages.

FLOODWAY - The channel of a river or stream and those parts of the flood plains adjoining the channel which carry and discharge the floodwater or floodflow of any river or stream.

INUNDATION - The covering by water of lands not normally so covered.

LAND TREATMENT AND MANAGEMENT MEASURES - Tillage practices, patterns of tillage or land use, or land management facility improvements to alter runoff, reduce sediment production, improve use of drainage and irrigation facilities, or improve plant or animal production.

LEVEE - An embankment, generally constructed on or parallel to the banks of a stream, lake or other body of water, for the purpose of protecting the land side from inundation by flood water or to confine the stream flow to its regular channel.

NONSTRUCTURAL FLOOD CONTROL MEASURES - Measures such as zoning ordinances and codes, flood forecasting, flood proofing, evacuation, flood fight activities, and upstream land treatment or management to control flood damages without physically restraining flood waters.

OPERATION, MAINTENANCE, AND REPLACEMENT COSTS (O M & R) - The value of goods and services needed to operate a constructed project and make repairs and replacements necessary to maintain the project in a sound operating condition during its economic life.

PEAK FLOW - The maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

RESIDUAL FLOOD DAMAGES - Those flood damages which are not prevented by a flood plain management program. They may or may not be preventible by other flood control measures (including both structural and nonstructural means).

STANDARD PROJECT FLOOD (S.P.F.) - A hypothetical flood representing the critical volume and peak discharge that may be expected from the most severe combination of meteorologic and hydrologic condition reasonably characteristic of the geographical region excluding extraordinarily rare combinations.

STORAGE, ACTIVE (USABLE) - The volume normally available for release from a reservoir below the stage of the maximum controllable level. (Total capacity less inactive and dead capacity).

STORAGE, DEAD - The volume of a reservoir below the still or invert of the lowest outlet.

STORAGE, FLOOD CONTROL - The space in reservoirs reserved for the sole purpose of regulating flood inflows to abate flood damage.

STORAGE, INACTIVE - The portion of live storage capacity from which water normally will not be withdrawn, in compliance with operating agreements or restrictions.

STORAGE, JOINT USE - The volume of a reservoir available to store water jointly for flood control and conservation purposes.

STORAGE, SURCHARGE - The volume of a reservoir between the maximum water surface elevation for which the dam is designed and the crest of an uncontrolled spillway, or the normal full-pool elevation with the crest gates in the normal closed position.

STORAGE, TOTAL - The total volume of a reservoir exclusive of surcharge.

STRUCTURAL MEASURES - Measures that delay, reduce, or control flood flows. These measures include reservoirs, channel improvements, levees, and diversion channels.

WATERSHED - All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream.

WATERSHED PROJECT - Comprehensive program of structural and non-structural measures to preserve or restore a watershed to good hydrologic conditions. These measures may include detention reservoirs, dikes, channels, contour trenches, terraces, furrows, gully plugs, revegetation, and possibly other practices to reduce flood peaks and sediment production.

PARTICIPATING STATES AND AGENCIES

STATES

Idaho	Nevada	Utah	Wyoming
Montana	Oregon	Washington	

FEDERAL AGENCIES

Department of Agriculture	Department of Housing &
Economic Research Service	Urban Development
Forest Service	Department of Transportation
Soil Conservation Service	Department of the Interior
Department of the Army	Bonneville Power Adm.
Corps of Engineers	Bureau of Indian Affairs
Department of Commerce	Bureau of Land Management
Economic Development Adm.	Bureau of Mines
National Oceanic & Atmospheric	Bureau of Outdoor Recreation
Administration	Bureau of Reclamation
National Weather Service	Fish and Wildlife Service
National Marine Fisheries	Geological Survey
Service	National Park Service
Department of Health, Education,	Department of Labor
& Welfare	Environmental Protection Agency
Public Health Service	Federal Power Commission